ANSWERS TO GAS LAWS

1. Let: P_1 = initial pressure = 82.6 kPa, V_1 = initial volume = 0.575 L
   P_2 = final pressure = ?, V_2 = final volume = 0.275 L

   $P_1 \cdot V_1 = P_2 \cdot V_2$ so that $P_2 = \frac{P_1V_1}{V_2} = \frac{82.6\text{ kPa} \times 0.575\text{ L}}{0.275\text{ L}}$ = **173 kPa**

2. Let: P_1 = initial pressure = 1.50×10^5 kPa, V_1 = initial volume = 25.0 mL
   P_2 = final pressure = 1.00×10^2 kPa, V_2 = final volume = ?

   $P_1 \cdot V_1 = P_2 \cdot V_2$ so that $V_2 = \frac{P_1V_1}{P_2} = \frac{1.50 \times 10^5\text{ kPa} \times 25.0\text{ mL}}{1.00 \times 10^2\text{ kPa}}$ = **3.75×10^4 mL**

3. Let: V_1 = initial volume = 2.50 L, T_1 = initial temperature = 5 + 273 = 278 K
   V_2 = final volume = ?, T_2 = final temperature = 10 + 273 = 283 K

   $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ so that $V_2 = \frac{V_1T_2}{T_1} = \frac{2.50\text{ L} \times 283\text{ K}}{278\text{ K}}$ = **2.54 L**

4. Let: V_1 = initial volume = 325 mL, T_1 = initial temperature = 25 + 273 = 298
   V_2 = final volume = 125 mL, T_2 = final temperature = ?

   $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ so that $T_2 = \frac{V_2T_1}{V_1} = \frac{125\text{ mL} \times 298\text{ K}}{325\text{ mL}}$ = 115 K = **–158°C**

5. Let: P_1 = initial pressure = 221 kPa, T_1 = initial temperature = 15 + 273 = 288K
   P_2 = final pressure = ?, T_2 = final temperature = 35 + 273 = 308 K

   $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ so that $P_2 = \frac{P_1T_2}{T_1} = \frac{221\text{ kPa} \times 308\text{ K}}{288\text{ K}}$ = **236 kPa**

6. Let: P_1 = initial pressure = 100 kPa, T_1 = initial temperature = 25 + 273 = 298 K
   P_2 = final pressure = 25.8 kPa, T_2 = final temperature = ?

   $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ so that $T_2 = \frac{P_2T_1}{P_1} = \frac{25.8\text{ kPa} \times 298\text{ K}}{100\text{ kPa}}$ = 76.9 K = **–196°C**

7. P = ?, V = 200.0 L, n = 2.00 mol, R = 8.31 $\frac{\text{kPa}\cdot\text{L}}{\text{mol}\cdot\text{K}}$, T= 0 + 273 = 273 K

   PV = nRT so that $P = \frac{nRT}{V} = \frac{2.00\text{ mol} \times 8.31\text{ kPa}\cdot\text{L/mol}\cdot\text{K} \times 273\text{ K}}{200.0\text{ L}}$ = **22.7 kPa**

8. P = 202.6 kPa, V = 3.50 L, n = ?, R = 8.31 $\frac{\text{kPa}\cdot\text{L}}{\text{mol}\cdot\text{K}}$, T = 35 + 273 = 308 K

   PV = nRT so that $n = \frac{PV}{RT} = \frac{202.6\text{ kPa} \times 3.50\text{ L}}{8.31\text{ kPa}\cdot\text{L/mol}\cdot\text{K} \times 308\text{ K}}$ = **0.277 mol**

9. P = 20.3 kPa, V = 2.75 L, n = moles N_2 = 1.54 g x $\frac{1\text{ mol}}{28.0\text{ g}}$ = 0.0550 mol, R = 8.31 $\frac{\text{kPa}\cdot\text{L}}{\text{mol}\cdot\text{K}}$, T = ?

   PV = nRT so that $T = \frac{PV}{nR} = \frac{20.3\text{ kPa} \times 2.75\text{ L}}{0.0550\text{ mol} \times 8.31\text{ kPa}\cdot\text{L/mol}\cdot\text{K}}$ = **122 K (–151°C)**

10. P = 66.7 kPa, V = ?, n = moles O_2 = 0.640 g x $\frac{1\,\text{mol}}{32.0\,\text{g}}$ = 0.0200 mol, R = 8.31 $\frac{\text{kPa}\cdot\text{L}}{\text{mol}\cdot\text{K}}$, T = –40+273 = 233 K

PV = nRT so that $V = \frac{nRT}{P} = \frac{0.0200\,\text{mol x } 8.31\,\text{kPa}\cdot\text{L / mol}\cdot\text{K x } 233\,\text{K}}{66.7\,\text{kPa}}$ = **0.581 L**

11. P = 23.3 kPa, V = 0.750 L, n = ?, R = 8.31 $\frac{\text{kPa}\cdot\text{L}}{\text{mol}\cdot\text{K}}$, T = 25 + 273 = 298 K

PV = nRT so that $n = \frac{PV}{RT} = \frac{23.3\,\text{kPa x } 0.750\,\text{L}}{8.31\,\text{kPa}\cdot\text{L / mol}\cdot\text{K x } 298\,\text{K}}$ = 0.007057 mol

molar mass = $\frac{0.500\,\text{g}}{0.007057\,\text{mol}}$ = **70.9 g/mol**

12. moles NO_2 = 9.20 g x $\frac{1\,\text{mol}}{46.0\,\text{g}}$ = 0.200 mol = moles C_2H_6 , mass C_2H_6 = 0.200 mol x $\frac{30.0\,\text{g}}{1\,\text{mol}}$ = **6.00 g**

NOTE: read the question – the gas conditions are irrelevant! (Tricky question)

13. P = 1.0 x 10^{-14} kPa, V = 1.00 mL = 1.00 x 10^{-3} L, n = ?, R = 8.31 $\frac{\text{kPa}\cdot\text{L}}{\text{mol}\cdot\text{K}}$, T = 0 + 273 = 273 K

PV = nRT so that $n = \frac{PV}{RT} = \frac{1.0 \text{ x } 10^{-14}\,\text{kPa x } 1.00 \text{ x } 10^{-3}\,\text{L}}{8.31\,\text{kPa}\cdot\text{L / mol}\cdot\text{K x } 273\,\text{K}}$ = 4.41 x 10^{-21} mol

# of molecules = 4.41 x 10^{-21} mol x $\frac{6.02 \text{ x } 10^{23}\text{ molecules}}{1\,\text{mol}}$ = **2.7 x 10^{3} molecules**

14. P = 507 kPa, V = 11.4 L, n = ?, R = 8.31 $\frac{\text{kPa}\cdot\text{L}}{\text{mol}\cdot\text{K}}$, T = 273 + 273 = 546 K

PV = nRT and $n = \frac{PV}{RT} = \frac{507\,\text{kPa x } 11.4\,\text{L}}{8.31\,\text{kPa}\cdot\text{L / mol}\cdot\text{K x } 546\,\text{K}}$ = 1.274 mol, molar mass = $\frac{20.4\,\text{g}}{1.274\,\text{mol}}$ = 16.0 g/mol

mass of one molecule = $\frac{16.0\,\text{g}}{1\,\text{mol}}$ x $\frac{1\,\text{mol}}{6.02 \text{ x } 10^{23}\text{ molec}}$ = **2.66 x 10^{-23} g/molec**

15. P = 86.4 kPa, V = 1.25 L, n = ?, R = 8.31 $\frac{\text{kPa}\cdot\text{L}}{\text{mol}\cdot\text{K}}$, T = 39 + 273 = 312 K

PV = nRT so that $n = \frac{PV}{RT} = \frac{86.4\,\text{kPa x } 1.25\,\text{L}}{8.31\,\text{kPa}\cdot\text{L / mol}\cdot\text{K x } 312\,\text{K}}$ = 0.04166 mol

molar mass = $\frac{1.75\,\text{g}}{0.04166\,\text{mol}}$ = **42.0 g/mol**

16. Assume 1.00 L of gas. Then mass of gas = 7.80 g and moles He = 7.80 g x $\frac{1\,\text{mol}}{4.0\,\text{g}}$ = 1.95 mol

P = ?, V = 1.00 L, n = 1.95 mol, R = $\frac{\text{kPa}\cdot\text{L}}{\text{mol}\cdot\text{K}}$, T = 273 + 273 = 546 K

PV = nRT so that $P = \frac{nRT}{V} = \frac{1.95\,\text{mol x } 8.31\,\text{kPa}\cdot\text{L / mol}\cdot\text{K x } 546\,\text{K}}{1.00\,\text{L}}$ = **8.8 x 10^{3} kPa**

17. moles of oxygen = 1.25 g x $\frac{1\,\text{mol}}{32.0\,\text{g}}$ = 0.03906 mol = moles of unknown

molar mass of unknown = $\frac{0.664\,\text{g}}{0.03906\,\text{mol}}$ = **17.0 g/mol**

18. Assume 1 L of gas**:** P = 100.0 kPa, V = 1.00 L, n = ?, R = 8.31 $\frac{kPa \cdot L}{mol \cdot K}$, T = –15 + 273 = 258 K

PV = nRT so that $n = \frac{PV}{RT} = \frac{100.0\ kPa \times 1.00\ L}{8.31\ kPa \cdot L/mol \cdot K \times 258\ K}$ = 0.04664 mol

mass of nitrogen gas = 0.04664 mol x $\frac{28.0\ g}{1\ mol}$ = 1.306 g **;** density = $\frac{m}{V} = \frac{1.306\ g}{L}$ = **1.31 g/L**

19. Let "1" = before: P_1 = 1621 kPa, V_1 = 11.0 L, $n_1 = n_2$ = constant, T_1 = 36 + 273 = 309 K
Let "2" = after: P_2 = 3647 kPa, V_2 = ?, T_2 = 16 + 273 = 289 K

$\frac{P_2V_2}{P_1V_1} = \frac{T_2}{T_1}$ so that $V_2 = \frac{P_1V_1T_2}{P_2T_1} = \frac{1621\ kPa \times 11.0\ L \times 289\ K}{3647\ kPa \times 309\ K}$ = **4.57 L**

20. Let "1" = before: $P_1 = P_2$ = constant, V_1 = 2.30 L, $n_1 = n_2$ = constant, T_1 = –100 + 273 = 173 K
Let "2" = after: V_2 = ?, T_2 = 25+273 = 298 K

$\frac{V_2}{V_1} = \frac{T_2}{T_1}$ so that $V_2 = \frac{V_1T_2}{T_1} = \frac{2.30\ L \times 298\ K}{173\ K}$ = **3.96 L**

21. P = 97.8 kPa, V = 45.3 mL = 0.0453 L, n = ?, R = 8.31 $\frac{kPa \cdot L}{mol \cdot K}$, T = 23 + 273 = 296 K

PV = nRT so that moles H_2 = $n = \frac{PV}{RT} = \frac{97.8\ kPa \times 0.0453\ L}{8.31\ kPa \cdot L/mol \cdot K \times 296\ K}$ = 1.80×10^{-3} mol

mass K = 1.80×10^{-3} mol H_2 x $\frac{2\ mol\ K}{1\ mol\ H_2}$ x $\frac{39.1\ g}{1\ mol\ K}$ = **0.141 g**

22. Let "1" = inside sphere: P_1 = ?, V_1 = 10.0 L, $n_1 = n_2$ = constant, T_1 = –10 + 273 = 263 K
Let "2" = outside sphere: P_2 = 100.0 kPa, V_2 = 1405 L, T_2 = 25 + 273 = 298 K

$\frac{P_1V_1}{P_2V_2} = \frac{T_1}{T_2}$ so that $P_1 = \frac{T_1P_2V_2}{T_2V_1} = \frac{263\ K \times 100.0\ kPa \times 1405\ L}{298\ K \times 10.0\ L}$ = **1.24 x 10^4 kPa**

PV = nRT so that $n = \frac{PV}{RT} = \frac{100.0\ kPa \times 1405\ L}{8.31\ kPa \cdot L/mol \cdot K \times 298\ K}$ = 56.74 mol

and mass O_2 = 56.74 mol x $\frac{32.0\ g}{1\ mol}$ = **1.82 x 10^3 g**

23. Let "1" = STP conditions: P_1 = 100.0 kPa, V_1 = ?, $n_1 = n_2$ = constant, T_1 = 0 + 273 = 273 K
Let "2" = given conditions: P_2 = 105 kPa, V_2 = 300 mL = 0.3 L, T_2 = 20 + 273 = 293 K

$\frac{P_1V_1}{P_2V_2} = \frac{T_1}{T_2}$ so that $V_1 = \frac{P_2V_2T_1}{P_1T_2} = \frac{105\ kPa \times 0.3\ L \times 273\ K}{100.0\ kPa \times 293\ K}$ = 0.293 L

Therefore**,** in 1 minute**:** V = 0.293 L x 20 = 5.87 L, which is about **6 L**

24. P = 100.0 kPa, V = ?, n = 1.00 mol, R = 8.31 $\frac{kPa \cdot L}{mol \cdot K}$, T = 20 + 273 = 293 K

PV = nRT so that $V = \frac{nRT}{P} = \frac{1.00\ mol \times 8.31\ kPa \cdot L/mol \cdot K \times 293\ K}{100.0\ kPa}$ = **24.3 L** (the density is not needed)

25. Let "1" = before conditions: P_1 = 202.6 kPa, $V_1 = V_2$ = constant, n_1 = 5.00 mol, T_1 = 25 + 273 = 298 K
Let "2" = after conditions**:** P_2 = 709.1 kPa, n_2 = 7.00 mol, T_2 = ?

$\frac{P_2}{P_1} = \frac{n_2T_2}{n_1T_1}$ so that $T_2 = \frac{P_2n_1T_1}{P_1n_2} = \frac{709.1\ kPa \times 5.00\ mol \times 298\ K}{202.6\ kPa \times 7.00\ mol}$ = **745 K (472°C)**

26. P = 100.0 kPa, V = 5.07 mL = 0.00507 L, n = ?, R = 8.31 $\frac{kPa \cdot L}{mol \cdot K}$, T = 0 + 273 = 273 K

PV = nRT so that $n = \frac{PV}{RT} = \frac{100.0\,kPa \times 0.00507\,L}{8.31\,kPa \cdot L / mol \cdot K \times 273\,K} = 2.235 \times 10^{-4}$ mol

molar mass = $\frac{0.00626\,g}{2.235 \times 10^{-4}\,mol}$ = 28.0 g/mol

Possible molar masses are: CO_2 = 44.0 g (no), H_2O = 18.0 g (no), N_2 = 28.0 g (this is it; contamination!)

27. Assume 1 mol of gas: density = $\frac{m}{V} = \frac{17.0\,g}{22.7\,L}$ = **0.749 g/L**

28. Let "1" = before: P_1 = 405.2 kPa, V_1 = 23.0 L, n_1 = 3.00 mol, T_1 = 100 + 273 = 373 K
Let "2" = after: P_2 = 100.0 kPa, V_2 = 50.0 L, n_2 = ?, T_2 = 400 + 273 = 673 K

$\frac{P_2V_2}{P_1V_1} = \frac{n_2T_2}{n_1T_1}$ and $n_2 = \frac{P_2V_2n_1T_1}{P_1V_1T_2} = \frac{100.0\,kPa \times 50.0\,L \times 3.00\,mol \times 373\,K}{405.2\,kPa \times 23.0\,L \times 673\,K}$ = 0.892 mol

Hence moles removed = 3.00 – 0.892 = 2.108 mol

and mass removed = 2.108 mol x $\frac{28.0\,g}{1\,mol}$ = **59.0 g**

29. moles of NH_3 = 15.0 g x $\frac{1\,mol}{17.0\,g}$ = 0.8824 mol (pressure and temperature are irrelevant)

moles of O_2 = 0.8824 mol NH_3 x $\frac{7\,mol\,O_2}{4\,mol\,NH_3}$ = 1.544 mol

Now: P = 95.0 kPa, V = ?, n = 1.544 mol, R = 8.31 $\frac{kPa \cdot L}{mol \cdot K}$, T = 150 + 273 = 423 K

PV = nRT so that volume of oxygen = $\frac{nRT}{P} = \frac{1.544\,mol \times 8.31\,kPa \cdot L / mol \cdot K \times 423\,K}{95.0\,kPa}$ = **57.1 L**

30. Let "1" = before: P_1 = 33.3 kPa, V_1 = 883.0 L, n_1 = 200.0 g x $\frac{1\,mol}{16.0\,g}$ = 12.5 mol, $T_1 = T_2$ = constant

Let "2" = after: P_2 = ?, V_2 = 500.0 L, n_2 = (200.0 g + 480.0 g) x $\frac{1\,mol}{16.0\,g}$ = 42.5 mol

$\frac{P_2V_2}{P_1V_1} = \frac{n_2}{n_1}$ so that $P_2 = \frac{P_1V_1n_2}{V_2n_1} = \frac{33.3\,kPa \times 883.0\,L \times 42.5\,mol}{500.0\,L \times 12.5\,mol}$ = **2.00 x 10^2 kPa**

31. This is an excess quantities problem.

H_2: P = 85.0 kPa, V = 15.0 L, n = ?, R = 8.31 $\frac{kPa \cdot L}{mol \cdot K}$, T = 150 + 273 = 423 K

PV = nRT so that $n = \frac{PV}{RT} = \frac{85.0\,kPa \times 15.0\,L}{8.31\,kPa \cdot L / mol \cdot K \times 423\,K}$ = 0.3627 mol (limiting)

Cl_2: P = 125.0 kPa, V = 12.0 L, n = ?, R = 8.31 $\frac{kPa \cdot L}{mol \cdot K}$, T = 100 + 273 = 373 K

PV = nRT so that $n = \frac{PV}{RT} = \frac{125.0\,kPa \times 12.0\,L}{8.31\,kPa \cdot L / mol \cdot K \times 373\,K}$ = 0.4839 mol

balanced equation is: $H_2 + Cl_2 \longrightarrow 2\,HCl$ so 0.3627 mol H_2 produces 0.7254 mol HCl

HCl: P = 120.0 kPa, V = ?, n = 0.7254 mol, R = 8.31 $\frac{kPa \cdot L}{mol \cdot K}$, T = 50 + 273 = 323 K

PV = nRT so that volume of HCl = $\frac{nRT}{P} = \frac{0.7254\,mol \times 8.31\,kPa \cdot L / mol \cdot K \times 323\,K}{120.0\,kPa}$ = **16.2 L**

32. Change in pressure = $1.930 \times 10^4 - 1.896 \times 10^4 = 3.4 \times 10^2$ kPa

$P = 3.4 \times 10^2$ kPa, V = 15.0 L, n = ?, R = $8.31 \frac{kPa \cdot L}{mol \cdot K}$, T = 21 + 273 = 294 K

PV = nRT so that moles of oxygen delivered = $n = \frac{PV}{RT} = \frac{3.4 \times 10^2 \text{ kPa} \times 15.0 \text{ L}}{8.31 \text{ kPa} \cdot \text{L/mol} \cdot \text{K} \times 294 \text{ K}} = 2.09$ mol

mass of oxygen delivered = 2.09 mol x $\frac{32.0 \text{ g}}{1 \text{ mol}}$ = **67 g**

33. Balanced reaction is $2\ NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$

moles of $(NH_4)_2SO_4$ required = 125 kg x $\frac{10^3 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol}}{132.1 \text{ g}}$ = 946.3 mol = moles H_2SO_4

moles NH_3 used = 946.3 mol $(NH_4)_2SO_4$ x $\frac{2 \text{ mol } NH_3}{1 \text{ mol } (NH_4)_2SO_4}$ = 1893 mol

volume of H_2SO_4 = $V = \frac{n}{c} = \frac{946.3 \text{ mol}}{9.00 \text{ mol/L}}$ = **105 L**

NH_3: $P = 2.53 \times 10^3$ kPa, V = ?, n = 1893 mol, R = $8.31 \frac{kPa \cdot L}{mol \cdot K}$, T = 5 + 273 = 278 K

PV = nRT and volume of NH_3 = $V = \frac{nRT}{P} = \frac{1893 \text{ mol} \times 8.31 \text{ kPa} \cdot \text{L/mol} \cdot \text{K} \times 278 \text{ K}}{2.53 \times 10^3 \text{ kPa}}$ = $\mathbf{1.73 \times 10^3}$ **L**

34. Let "1" = before: $P_1 = 3.60$ kPa, $V_1 = 700.0$ mL = V_2 = constant, $n_1 = 0.00100$ mol, $T_1 = T_2$ = constant

Let "2" = after: $P_2 = 20.0$ kPa, n_2 = ?

$\frac{P_2}{P_1} = \frac{n_2}{n_1}$ so that $n_2 = \frac{P_2 n_1}{P_1} = \frac{20.0 \text{ kPa} \times 0.00100 \text{ mol}}{3.60 \text{ kPa}} = 0.00556$ mol

Hence: moles N_2 added = 0.00556 – 0.00100 = **0.00456 mol**

35. moles H_2 = 0.712 g x $\frac{1 \text{ mol}}{2.0 \text{ g}}$ = 0.356 mol, but if $P_1 = P_2$, $V_1 = V_2$ and $T_1 = T_2$ then must have $n_1 = n_2$

Hence: moles unknown gas = 0.356 mol and molar mass = $\frac{13.0 \text{ g}}{0.356 \text{ mol}}$ = **37 g/mol**

36. Let "1" = before (2.00 L tank), "2" = before (1.00 L vessel), and "3" = after (1.00 L vessel)

Original moles of F_2: $P_1 = 126$ kPa, $V_1 = 2.00$ L, n_1 = ?, R = $8.31 \frac{kPa \cdot L}{mol \cdot K}$, $T_1 = 30 + 273 = 303$ K

PV = nRT so that $n_1 = \frac{P_1V_1}{RT_1} = \frac{126 \text{ kPa} \times 2.00 \text{ L}}{8.31 \text{ kPa} \cdot \text{L/mol} \cdot \text{K} \times 303 \text{ K}} = 0.100$ mol of F_2

moles of Xe used: $P_2 = 50.4$ kPa, $V_2 = 1.00$ L, n_2 = ?, R = $8.31 \frac{kPa \cdot L}{mol \cdot K}$, $T_2 = 30 + 273 = 303$ K

$n_2 = \frac{P_2V_2}{RT_2} = \frac{50.4 \text{ kPa} \times 1.00 \text{ L}}{8.31 \text{ kPa} \cdot \text{L/mol} \cdot \text{K} \times 303 \text{ K}} = 0.0200$ mol of Xe

moles F_2 reacted = 0.0200 mol Xe x $\frac{2 \text{ mol } F_2}{1 \text{ mol Xe}}$ = 0.0400 mol

moles F_2 left over= original moles F_2 – moles F_2 reacted = 0.100 – 0.040 = 0.060 mol

P_3 = ?, $V_3 = 1.00$ L, $n_3 = 0.100 - 0.0400 = 0.060$ mol, R = $8.31 \frac{kPa \cdot L}{mol \cdot K}$, $T_3 = -10 + 273 = 263$ K

PV = nRT so that $P_3 = \frac{n_3RT_3}{V_3} = \frac{0.060 \text{ mol} \times 8.31 \text{ kPa} \cdot \text{L/mol} \cdot \text{K} \times 263 \text{ K}}{1.00 \text{ L}}$ = $\mathbf{1.3 \times 10^2}$ **kPa**