Chapter 12: Gases

For the ease of writing out workings below I have rounded some answers (within a question) to four significant figures. However, often it is best to keep the answer 'in' your calculator to use in the next part of a multi-step calculation. Therefore answers below may vary slightly from yours.

1. Convert the following:

(a) 75ºC to K
(b) 50K to ºC
(c) 25m^3 to cm^3
(d) 100cm^3 to m^3
(e) 50kPa to Pa
(f) 87Pa to kPa
(g) 7.2L to m^3
(h) 4000cm^3 to L
(i) 1.4m^3 to L

(a) 75 + 273.15 = 348.15K
(b) 50 - 273.15 = -223.15ºC
(c) 25 x 10^6 = 25,000,000 cm^3
(d) 100 ÷ 10^6 = 1x10^{-4} m^3 (0.0001 m^3)
(e) 50 x 1000 = 50,000 Pa
(f) 87 ÷ 1000 = 0.087 kPa
(g) 7.2 ÷ 1000 = 7.2x10^{-3} m^3 (0.0072 m^3)
(h) 4000 ÷ 1000 = 4 L
(i) 1.4 x 1000 = 1400 L

2. At constant temperature, how does the volume of a gas change when its pressure increases?

At constant temperature, when the pressure increases, the volume decreases.

3. Give (a) a written version, and (b) a mathematical representation of (i) Boyle's law, (ii) Charles's law, (iii) Avogadro's law.

(a)(i) Boyle's law states that, at constant temperature, the volume of a fixed mass of gas is inversely proportional to its pressure.

(ii) Charles's law states that, at constant pressure, the volume of a fixed mass of gas is directly proportional to its temperature in Kelvin

(iii) Avogadro's law states that equal volumes of gases at the same temperature and pressure contain equal numbers of particles.

(b)(i) $V \propto \frac{1}{p}$ (ii) $V \propto T$ (iii) $V \propto n$

4. Which gas law is depicted by the diagram below?

Charles's law

5. (a) What is an ideal gas? (b) State the ideal gas equation. (c) What physical quantity is represented by each of the following symbols in the ideal gas equation (i) P, (ii) V, (iii) T?

(a) An ideal gas is a hypothetical gas that obeys the gas laws perfectly under all conditions of temperature and pressure.

(b) PV = nRT

(c) (i) Pressure, (ii) Volume, (iii) Temperature

6. A racing car tyre contained 294g of nitrogen gas occupying a volume of $0.168m^3$ at a temperature of 293K. Calculate the pressure of the gas inside the tyre in Pa.

PV = nRT

P = ?
V = $0.168m^3$
n = 294g of nitrogen gas = $\frac{294}{M_r} = \frac{294}{28.02}$ = 10.49 (or 10.49250535) moles
R = 8.314
T = 293K

$P = \frac{nRT}{V}$

$P = \frac{(10.49)(8.314)(293)}{(0.168)}$

P = 152,105.12 Pa (or 1.521×10^5 Pa)

7. Assuming ideal behaviour, how many moles of carbon dioxide are present in $720cm^3$ of the gas at 10°C and a pressure of $1x10^5$ Pa?

PV = nRT

P = $1x10^5$ Pa
V = $720cm^3 \div 10^6 = 7.2x10^{-4}$ m^3
n = ?
R = 8.314
T = 10°C + 273.15 = 283.15

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

$n = \frac{(1x10^5)(7.2x10^{-4})}{(8.314)(283.15)}$

n = 0.0305848… 0.03058 moles

8. Carbon dioxide is stored under pressure in liquid form in a fire extinguisher. Two kilograms of carbon dioxide are released into the air as a gas on the discharge of the fire extinguisher. What volume does this gas occupy at a pressure of $1.01x10^5$ Pa and a temperature of 290K?

PV = nRT

P = $1.01x10^5$ Pa
V = ?
n = 2kg x 1000 = 2000g ÷ 44.01 = 45.44 moles (or 45.44421722)
R = 8.314
T = 290K

$$V = \frac{nRT}{P}$$

$$V = \frac{(45.44)(8.314)(290)}{1.01 \times 10^5}$$

V = 1.084738281…. V = 1.085 m^3

9. Calculate the number of moles of nitrogen gas at a pressure of 1.85 x 10^5 Pa and a temperature of 293K in the 6.5 x 10^{-5} m^3 volume inside a new tennis ball.

PV = nRT

P = 1.85x10^5 Pa
V = 6.5 x 10^{-5} m^3
n = ?
R = 8.314
T = 293

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

$$n = \frac{(1.85 \times 10^5)(6.5 \times 10^{-5})}{(8.314)(293)}$$

n = 4.936367047x10^{-3}… 4.936x10^{-3} = 0.004936 moles

10. A 3.50g sample of a gaseous compound occupies 10.0 litres at a pressure of 120 kPa and a temperature of 25°C. Calculate, to the nearest whole number, the relative molecular mass of the gas.

PV = nRT

P = 120 kPa x 1000 = 120,000 Pa
V = 10 litres (1L = 1000cm^3) = 10,000 cm^3 ÷ 10^6 = 0.01 m^3
n = ?
R = 8.314
T = 25 + 273.15 = 298.15°C

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

$$n = \frac{(120{,}000)(0.01)}{(8.314)(298.15)}$$

n = 0.484101482 = 0.4841 moles

0.4841 moles = 3.50 g

$$1 \text{ mole} = \frac{3.50}{0.4841}$$

1 mole = 7.229911175… To the nearest whole number = 7

11. A 28 g sample of a gaseous compound occupies 12,000 cm^3 at a pressure of 100 kPa and a temperature of 27°C. Calculate the relative molecular mass of the gas.

PV = nRT

P = 100 kPa x 1000 = 100,000 Pa
V = 12,000 $cm^3 \div 10^6$ = 0.012 m^3
n = ?
R = 8.314
T = 27 + 273.15 = 300.15

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

$$n = \frac{(100,000)(0.012)}{(8.314)(300.15)}$$

0.4808757517 moles = 28g

$$1 \text{ mole} = \frac{28}{0.4808757517}$$

= 58.227099 = 58.23

12. To determine the M_r of compound X, a volatile liquid, a small volume of X was vapourised in a suitable container. Calculate, correct to the nearest whole number, the relative molecular mass of X, given that 0.22g of X occupied a volume of 76cm^3 at a pressure of 1.011×10^5 Pa and a temperature of 99°C.

PV = nRT

P = 1.011×10^5 Pa
V = 76 $cm^3 \div 10^6 = 7.6 \times 10^{-5}$ m^3
n = ?
R = 8.314
T = 99 + 273.15 = 372.15

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

$$n = \frac{(1.011 \times 10^5)(7.6 \times 10^{-5})}{(8.314)(372.15)}$$

n = $2.483342976 \times 10^{-3}$ moles

$2.483342976 \times 10^{-3}$ moles = 0.22 g
1 mole = 88.59026218

1 mole = 88.59 – nearest whole number = 89

13. (i) Explain how real gases behave differently to ideal gases. (ii) Under what conditions of temperature and pressure does the ideal gas law most accurately describe real gas behaviour? (iii) Give two reasons why carbon dioxide deviates from ideal gas behaviour.

(i) the volume of particles is not negligible, have intermolecular forces between particles etc.
(ii) high temperature, low pressure
(iii) CO_2 has intermolecular forces between molecules / CO_2 molecules have volume / collisions not perfectly elastic