1.

a. Any three of the following

- *Carbon dioxide (CO_2)*
- *Methane (CH_4)*
- *Water vapour (H_2O)*
- *Nitrous oxide (NO_2)*
  1-----mark

b. Describe type of energy and absorption:

- *Shortwave UV energy from the Sun is absorbed by the Earth and re-emitted as **low** energy infrared radiation(IR) 1-----mark*
- *Due to the molecular properties of greenhouse gases they absorb IR emitted from Earth's surface 1-----mark, thus causing the atmosphere to trap heat, which contributes to global warming and climate change 1----mark*

2. Gas pressure is the force per unit area exerted by all gas molecules as they collide with the walls of their container.
1----- mark for mentioning force due to collisions over a certain area,
1----- mark for mentioning it is the total amount of molecules that collectively contribute to the pressure.

3. Given: SLC (0°C (273 K), 100 kPa), molar volume of an ideal gas = 24.8 L/mol.

a. 5.00 g N_2

- *Molar mass N_2 = 28.02 g/mol*
- *Moles:* $n = \frac{5.00}{28.02} = 0.1784$ *mol 1-----mark*
- *Volume = n X 24.8 L = 0.1784 X 24.8 = 4.43 L 1-----mark*

b. 1.80 g H_2O

- *Molar mass H_2O = 18.02 g/mol*
- *Moles:* $n = \frac{1.80}{18.02} = 0.0999$ *mol 1-----mark*
- *Volume:* $V = 0.0999 \times 24.8 = 2.48$ *1-----mark*

4. V = 2.50 L, P = 100 kPa, T = 35°C = 308 K, R = 8.314 kPa·L·K $^{-1}$·mol $^{-1}$

$$n = \frac{PV}{RT} = \frac{100 \times 2.50}{8.314 \times 308} = \frac{250}{2560.712} = 0.0976\ mol$$

1-----mark for correct formula,

1-----mark for correct calculation

5. Volume of gas mixture

Given: *0.140 g N_2 and 0.640 g O_2, P = 100 kPa, T = 25°C = 298 K, R = 8.314 kPa·L·K $^{-1}$·mol $^{-1}$*

- *Moles N_2: $n = 0.140/28.02 = 0.004996\ mol$*
- *Moles O_2: $n = 0.640/32.00 = 0.0200\ mol$*
  1-----mark for mols of each gas
- *Total moles: $n_{total} = 0.004996 + 0.0200 = 0.024996 \approx 0.0250$*
  1-----mark for total (consequential marks apply)

$$V = \frac{nRT}{P} = \frac{0.0250 \times 8.314 \times 298}{100} = \frac{61.86}{100} = 0.61942\ L = 0.619\ L$$

1-----mark for correct formula and calculation

1-----mark for correct number of sig figs.

6. *Mg + 2HCl → $MgCl_2$ + H_2*

*Given**:** 20.0 mL H_2 produced at SLC, molar volume 24.8 L/mol*

- *Volume: 20.0 mL = 0.0200 L*
- *Moles H_2: $n = \frac{V}{24.8} = \frac{0.0200}{24.8} = 8.10 \times 10^{-4} mol$ 1-----mark*
- *Stoichiometry: 1 mol Mg : 1 mol H_2 →*
  => moles Mg = 8.01 × 10 $^{-4}$ mol 1-----mark
- *Mass Mg: $m = n \times M = 8.01 \times 10^{-4} \times 24.31 = 0.0196\ g$ 1-----mark correct value*

7. *Mass of CO_2*

Given: V = 21.1 L, P = 110 kPa, T = 30°C = 303 K, R = 8.314 kPa·L·K $^{-1}$·mol $^{-1}$

$$n = \frac{PV}{RT} = \frac{110 \times 21.1}{8.314 \times 303} = \frac{2321}{2518.842} = 0.921\ mol$$

1-----mark

- *Mass CO_2 = n × M = 0.921 × 44.01 = 40.5 g   1-----mark*

8. $CaCO_3 \rightarrow CaO + CO_2$

Given: *mass $CaCO_3$ = 2.48 kg = 2480 g*

- *Molar mass $CaCO_3$ = 100 g/mol*
- *Moles CO_2 = moles $CaCO_3$ = 2480 / 100 = 24.8 mol   1-----mark*
- *V = 300 L, P = 400 kPa, R = 8.314, T = ?*

$T = \frac{PV}{nR} = \frac{400 \times 300}{24.8 \times 8.314} = \frac{120000}{206.0} = 582$ *1-----mark*

- *T(°C) = 582 - 273 = 309°C   1-----mark*

9. $3H_2 + N_2 \rightarrow 2NH_3$

a. To find the excess reactant we
- first find the mol of each reactant added.
=> $n_{(nitrogren)}$ =4.96/24.8 = 0.200
=> $n_{(hydrogen)}$ = 9.92/24.8 =0.400
1-----mark for the mol of each gas
- next we divide by the equation coefficient and take the lowest value as the limiting reactant
=> (N_2) 0.200/1 = 0.200 : (H_2) 0.400/3= 0.133
Hydrogen is the limiting reactant hence Nitrogen is in excess.
1-----mark for correctly identifying the excess reactant.

b. If 0.400 mol of hydrogen gas reacts it will use up 1/3 X 0.400 mol of N_2 gas
1-----mark for using the correct stoichiometric ratio

=> Excess N_2 remaining is 0.200 – 0.133 = 0.066 mol

1-----mark

c. If 0.400 mol of H_2 reacts completely it will form (2/3 X 0.400) 0.266 mol of NH_3

1-----mark for correct stoichiometric ratio

1-----mark for correct mol given to the right number of sig figs.

d. Pressure: $P = \frac{nRT}{V} = \frac{(0.266+0.066)\times 8.314\times(390+273)}{300}$

$$= 6.67\ kPa$$

1-----mark for calculating the total number of mol of gas remaining .

1-----mark for correct equation and value to 3 sig figs (consequential marks given)

10. CO_2 concentration in ppm

Given

- Volume of exhaust gas sample = 1.00 L
- Mass of CO_2 in sample = 4.40×10^{-4} g
- Molar mass of CO_2 = 44.0 g mol^{-1}(from Data book)
- Molar volume at SLC = 24.8 L mol^{-1} (from Data book)

Step 1 - Convert mass of CO_2 to moles

$$n(CO_2) = \frac{4.40 \times 10^{-4}}{44.0}$$
$$n(CO_2) = 1.00 \times 10^{-5}\ mol$$

1-----mark

Step 2 - Convert moles of CO_2 to volume at SLC

$$V(CO_2) = n \times V_m$$
$$V(CO_2) = (1.00 \times 10^{-5}) \times 24.8$$
$$V(CO_2) = 2.48 \times 10^{-4}\ L$$

1-----mark

Step 3 - Calculate volume fraction of CO_2

Total exhaust volume = 2.00 L

$$\text{Volume fraction} = \frac{2.48 \times 10^{-4}}{2.00}$$
$$= 1.24 \times 10^{-4}$$

1-----mark

Step 4 - Convert to ppm (v/v)

$$ppm = (1.24 \times 10^{-4}) \times 10^{6}$$

[CO_2] = 124 ppm (v/v)

1-----mark

b. Calculating the total volume of CO_2 in the 4523 L sample.

=> $\frac{124}{10^6}$ x $4523 = 0.561$ litres

1-----mark for correct calculation (consequential marks awarded)

1-----mark for correct sig figs