The Ideal Gas Equation

Question Paper 6

Level	A Level
Subject	Chemistry
Exam Board	AQA
Module	3.1 Physical Chemistry
Topic	3.1.2 Amount of Substance
Sub-Topic	3.1.2.3 The Ideal Gas Equation
Booklet	Question Paper 6

Time Allowed: **58 minutes**

Score: **/58**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	75%	70%	60%	55%	50%	<50%

Q1. (a) A sample of ethanol vapour, C_2H_5OH (M_r = 46.0), was maintained at a pressure of 100 kPa and at a temperature of 366K.

(i) State the ideal gas equation.

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(ii) Use the ideal gas equation to calculate the volume, in cm^3, that 1.36 g of ethanol vapour would occupy under these conditions.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

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(5)

(b) Magnesium nitride reacts with water to form magnesium hydroxide and ammonia.

(i) Balance the equation, given below, for the reaction between magnesium nitride and water.

$$Mg_3N_2 + H_2O \rightarrow Mg(OH)_2 + NH_3$$

(ii) Calculate the number of moles, and hence the number of molecules, of NH_3 in 0.263 g of ammonia gas.
(The Avogadro constant L = 6.02 × 10^{23} mol^{-1})

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(c) Sodium carbonate is manufactured in a two-stage process as shown by the equations below.

$$NaCl + NH_3 + CO_2 + H_2O \rightarrow NaHCO_3 + NH_4Cl$$

$$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$$

Calculate the maximum mass of sodium carbonate which could be obtained from 800 g of sodium chloride.

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(4)
(Total 13 marks)

Q2. Which one of the following samples of gas occupies the largest volume?

A 1.0 g of ozone (O_3) at l00 kPa and 300 K

B 1.0 g of oxygen at 100 kPa and 300 K

C 1.0 g of water vapour at 250 kPa and 450 K

D 1.0 g of methane at 333 kPa and 500 K

(Total 1 mark)

Q3. What is the volume occupied by 10.8 g of the freon CCl_2F_2 at 100 kPa and 273 K?

A 2.02 dm^3

B 2.05 dm^3

C 2.02 cm^3

D 2.05 cm^3

(Total 1 mark)

Q4. Which one of the following samples of gas, when sealed into a vessel of volume 0.10 m^3, is at the highest pressure?

A 1.6 g of helium (He) at 100 K

B 1.6 g of methane (CH_4) at 100 K

C 1.6 g of oxygen (O_2) at 600 K

D 1.6 g of sulphur dioxide (SO_2) at 1200 K

(Total 1 mark)

Q5. On complete combustion, 0.0150 mol of an organic acid produced 735 cm^3 of carbon dioxide (measured at 101 kPa and 298 K). The same amount of acid required 15.0 cm^3 of 2.00 M sodium hydroxide solution for neutralisation. Which one of the following could be the formula of the acid?

A HCOOH

B CH_3COOH

C HOOCCOH

D $HOOCCH_2CH_2COOH$

(Total 1 mark)

Q6. Which one of the following contains the smallest number of moles of carbon dioxide gas?

A 2.65 g

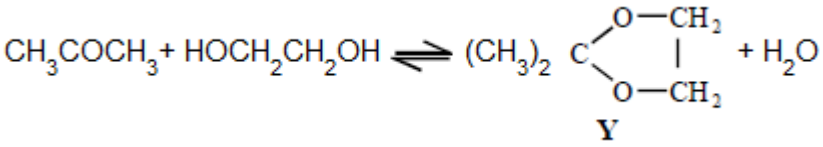
B 0.0150 m^3 at 1000 K and 33.0 kPa

C 1.50 dm^3 at 327 °C and 200 kPa

D 1500 cm^3 at 300 K and 100 kPa

(Total 1 mark)

Q7. This question is about the reaction between propanone and an excess of ethane-1,2-diol, the equation for which is given below.



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In a typical procedure, a mixture of 1.00 g of propanone, 5.00 g of ethane-1,2-diol and 0.100 g of benzenesulphonic acid, $C_6H_5SO_3H$, is heated under reflux in an inert solvent. Benzenesulphonic acid is a strong acid.

If 1.00 g of propanone was vapourised at 100 °C and 100 kPa pressure, the volume in m^3 of gas formed would be

A 31.0

B 8.31

C 0.534

D 5.34×10^{-4}

(Total 1 mark)

Q8. (a) The mass of one mole of $_1H$ atoms is 1.0078 g and that of one $_1H$ atom is 1.6734×10^{-24} g.
Use these data to calculate a value for the Avogadro constant accurate to five significant figures. Show your working.

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(2)

(b) How does the number of atoms in one mole of argon compare with the number of molecules in one mole of ammonia?

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(1)

(c) A sample of ammonia gas occupied a volume of 0.0352 m^3 at 298 K and 98.0 kPa. Calculate the number of moles of ammonia in the sample.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

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(3)

(d) A solution containing 0.732 mol of ammonia was made up to 250 cm^3 in a volumetric flask by adding water. Calculate the concentration of ammonia in this final solution and state the appropriate units.

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(e) A different solution of ammonia was reacted with sulphuric acid as shown in the equation below.

$$2NH_3(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq)$$

In a titration, 25.0 cm^3 of a 1.24 mol dm^{-3} solution of sulphuric acid required 30.8 cm^3 of this ammonia solution for complete reaction.

(i) Calculate the concentration of ammonia in this solution.

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(ii) Calculate the mass of ammonium sulphate in the solution at the end of this titration.

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(6)

(f) The reaction of magnesium nitride, Mg_3N_2, with water produces ammonia and magnesium hydroxide. Write an equation for this reaction.

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(2)

(Total 16 marks)

Q9. When a sample of liquid, **X,** of mass 0.406 g was vaporised, the vapour was found to occupy a volume of 2.34×10^{-4} m^3 at a pressure of 110 kPa and a temperature of 473 K.

(a) Give the name of the equation $pV = nRT$.

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(1)

(b) Use the equation $pV = nRT$ to calculate the number of moles of **X** in the sample and hence deduce the relative molecular mass of **X.**
(The gas constant R = 8.31 J K^{-1} mol^{-1})

*Moles of **X*** .....

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*Relative molecular mass of **X*** .....

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(4)

(c) Compound **X,** which contains carbon, hydrogen and oxygen only, has 38.7% carbon and 9.68% hydrogen by mass. Calculate the empirical formula of **X**.

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(d) Using your answers to parts (b) and (c) above, deduce the molecular formula of **X**.

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(1)
(Total 9 makrs)

Q10. This question relates to the equilibrium gas-phase synthesis of sulphur trioxide:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Thermodynamic data for the components of this equilibrium are:

Substance	$\Delta H_f^{\ominus}$ / kJ mol^{-1}	$S^{\ominus}$ / J K^{-1} mol^{-1}
$SO_3(g)$	−396	+257
$SO_2(g)$	–297	+248
$O_2(g)$	0	+204

This equilibrium, at a temperature of 585 K and a total pressure of 540 kPa, occurs in a vessel of volume 1.80 dm^3. At equilibrium, the vessel contains 0.0500 mol of $SO_2(g)$, 0.0800 mol of $O_2(g)$ and 0.0700 mol of $SO_3(g)$.

At equilibrium in the same vessel of volume 1.80 dm^3 under altered conditions, the reaction mixture contains 0.0700 mol of $SO_3(g)$, 0.0500 mol of $SO_2(g)$ and 0.0900 mol of $O_2(g)$ at a total pressure of 623 kPa. The temperature in the equilibrium vessel is

A 307 °C

B 596 K

C 337 °C

D 642 K

(Total 1 mark)

Q11. Nitrogen dioxide dissociates according to the following equation.

$$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$$

When 21.3 g of nitrogen dioxide were heated to a constant temperature, *T*, in a flask of volume 11.5 dm^3, an equilibrium mixture was formed which contained 7.04 g of oxygen.

(a) (i) Calculate the number of moles of oxygen present in this equilibrium mixture and deduce the number of moles of nitrogen monoxide also present in this equilibrium mixture.

Number of moles Of O_2 at equilibrium .....

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Number of moles of NO at equilibrium .....

(ii) Calculate the number of moles in the original 21.3 g of nitrogen dioxide and hence calculate the number of moles of nitrogen dioxide present in this equilibrium mixture.

Original number of moles of NO_2 .....

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Number of moles of NO_2 at equilibrium .....

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(4)

(b) Write an expression for the equilibrium constant, K_c, for this reaction. Calculate the value of this constant at temperature T and give its units.

Expression for K_c .....

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Calculation .....

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(4)

(c) The total number of moles of gas in the flask is 0.683. Use the ideal gas equation to determine the temperature *T* at which the total pressure in the flask is 3.30×10^5 Pa. (The gas constant *R* = 8.31 J $K^{-1}mol^{-1}$)

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(d) State the effect on the equilibrium yield of oxygen and on the value of K_c when the same mass of nitrogen dioxide is heated to the same temperature *T*, but in a different flask of greater volume.

Yield of oxygen .....

Value of K_c .....

(2)
(Total 13 marks)