Year End Review: Moles in Chemistry

Sahil Thorul and Kieran Vanapalli

Here are some review questions related to moles that you can practice inorder to prepare for the exam.

Formulas:	Constants / Conversion Factors:
$n = m / M$ $n = p / N_A$ $n = cV$ $PV = nRT$ (Ideal gas law) $c_1V_1 = c_2V_2$ (Dillution) $n = V / 22.7$ (at STP conditions)	N_A (Avagadro's #) = 6.02×10^{23} R (Universal Gas Constant) = 8.314 STP conditions = 273 K, 100 kPa or 1 atm 0^0 C = 273 K 1 dm^3 = 1 L = 1 000 mL = 1×10^3 cm^3

Multiple Choice:

1. What is the total number of hydrogen atoms in 1.0 mol of benzamide, $C_6H_5CONH_2$?

A. 7 B. 6.0×10^{23} C. 3.0×10^{24} D. 4.2×10^{24}

2. Which sample has the greatest mass?

A. 1 mol of SO_2 B. 2 mol of N_2O C. 2 mol of Ar D. 4 mol of NH_3

3. The relative molecular mass of a gas is 56 and its empirical formula is CH_2. What is the molecular formula of the gas?

A. CH_2 B. C_2H_4 C. C_3H_6 D. C_4H_8

4. Which non-metal forms an oxide XO_2 with a relative molecular mass of 60 g mol^{-1}?

A. C B. N C. Si D. S

5. What is the mass, in g, of one molecule of ethane?

A. 3.0×10^{-23} B. 5.0×10^{-23} C. 30 D. 1.8×10^{25}

6. What is the number of moles of $Mg(NO_3)_2$ needed to prepare 500 cm_3 of a 0.0450 mol dm^{-3} solution?

A. 0.900 B. 0.225 C. 0.0225 D. 1.11

7. 1.7 g of sodium nitrate, $NaNO_{3(s)}$, is dissolved in water to prepare 0.02 L of solution. What is the concentration of the resulting solution in mol L^{-1} ?

A. 0.01 B. 0.10 C. 0.20 D. 1.0

8. How many atoms of sodium will be present in 4.05 mL of a 3.183 mol L-1 solution of Na_2O?

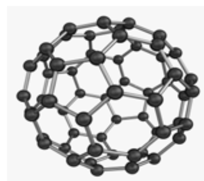
A. 1.55×10^{22} B. 7.76×10^{24} C. 1.53×10^{24} D. 6.02×10^{23}

9. A 40.0 g gas sample occupies 11.2 L at STP. What is the molecular mass of the gas, in g mol^{-1}?

A. 5.00 B. 800 C. 80.0 D. 0.5

10. What is the amount of carbon, in mol, in 0.36 kg of a buckyball (C60)?

A. 5.0×10^{-4} B. 5.0×10^{-3} C. 5.0×10^{-2} D. 5.0×10^{-1}



Short Answer:

11. 4.00 mol of a hydrocarbon with an empirical formula of CH2 has a mass of 280 g. What is the molecular formula of this compound?

12. 6.0 mol of aluminum reacts with oxygen to form aluminum oxide. What is the amount of oxygen, in g, needed for complete reaction?

13. What is the maximum mass, in g, of magnesium oxide that can be obtained from the reaction of 2.4 g of magnesium with excess oxygen?

14. What is the final concentration of NaCl if 2.00 L of 3.00 M NaCl and 4.00 L of 1.50 M NaCl are mixed?

15. What is the volume occupied by 3.00 moles of gas at 24.0 °C and 101.6 kPa?

Longer Answer:

16. 0.600 mol of aluminum hydroxide is mixed with 0.600 mol of sulfuric acid and the following reaction occurs (the equation is not balanced): $Al(OH)_{3(s)} + H_2SO_{4(aq)} \rightarrow Al_2(SO_4)_{3(aq)} + H_2O_{(l)}$

a) Balance the equation and determine the limiting reagent.
b) Calculate the mass of $Al_2(SO_4)_3$ produced.
c) Determine the mass of the excess reactant that remains.

17. The reaction of 4.25 g of Cl_2 with 2.20 g of P_4 produces PCl_5.

a) Write the balanced chemical equation and determine the limiting reagent.
b) Calculate the mass of PCl_5 produced.
c) In a lab experiment, 12.3 g of PCl_5 was produced. Calculate the percentage yield.

18. How much 0.20 M phosphoric acid is needed to react with 100 mL of 0.10 M sodium hydroxide?

19. 13.9 g of an unknown gas is placed in a 5.00 L container with an initial pressure at 58.6 kPa and initial temperature at 60.0 °C. What is the identity of this gas?

20. 1.65 g of aluminium metal reacts with 50.0 mL of 2.00 mol dm-3 hydrochloric acid to form hydrogen gas. The hydrogen gas is collected at 25.0 °C and 96.9 kPa. What is the volume of hydrogen gas collected?

Here are some IB-style questions that you can do for further practice:

Short Questions:

1. A toxic gas, A, consists of 53.8 % nitrogen and 46.2 % carbon by mass. At 273 K and 1.01×10^5 Pa, 1.048 g of A occupies 462 cm^3.

a) Determine the empirical formula of A. **(1 mark)**
b) Calculate the molar mass of the compound. **(1 mark)**
c) Draw its molecular (Lewis) structure. **(1 mark)**

2. Smog is common in cities throughout the world. One component of smog is PAN (peroxyacylnitrate) which consists of 20.2 % C, 11.4 % N, 65.9 % O and 2.50 % H by mass. Determine the empirical formula of PAN. **(3 marks)**

Long Questions:

3. 0.600 mol of aluminium hydroxide is mixed with 0.600 mol of sulfuric acid, and the following reaction occurs: $2Al(OH)_3(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + 6H_2O(l)$

(a) Determine the limiting reactant.

(2)

(b) Calculate the mass of $Al_2(SO_4)_3$ produced.

(2)

(c) Determine the amount (in mol) of excess reactant that remains.

(1)

(d) Define a *Brønsted-Lowry acid* and a *Lewis base*.

(2)

(e) $H_2SO_4(aq)$ is a strong acid. State the name and the formula of any weak acid.

4. Brass is a copper containing alloy with many uses. An analysis is carried out to determine the percentage of copper present in three identical samples of brass. The reactions involved in this analysis are shown below.

Step 1: $Cu(s) + 2HNO_3(aq) + 2H^+(aq) \rightarrow Cu^{2+}(aq) + 2NO_2(g) + 2H_2O(l)$

Step 2: $4I^-(aq) + 2Cu^{2+}(aq) \rightarrow 2CuI(s) + I_2(aq)$

Step 3: $I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$

(a) (i) Deduce the change in the oxidation numbers of copper and nitrogen in step 1.

Copper: Nitrogen:

(2)

(ii) Identify the oxidizing agent in step 1.

(1)

(b) A student carried out this experiment three times, with three identical small brass nails, and obtained the following results.

Mass of brass = 0.456 g ± 0.001 g

Titre	**1**	**2**	**3**
Initial volume of 0.100 mol dm^{-3} $S_2O_3^{2-}$ (± 0.05 cm^3)	0.00	0.00	0.00
Final volume of 0.100 mol dm^{-3} $S_2O_3^{2-}$ (± 0.05 cm^3)	28.50	28.60	28.40
Volume added of 0.100 mol dm^{-3} $S_2O_3^{2-}$ (± 0.10 cm^3)	28.50	28.60	28.40
Average volume added of 0.100 mol dm^{-3} $S_2O_3^{2-}$ (± 0.10 cm^3)	28.50		

(i) Calculate the average amount, in mol, of $S_2O_3^{2-}$ added in step 3.

(2)

(ii) Calculate the amount, in mol, of copper present in the brass.

(1)

(iii) Calculate the mass of copper in the brass.

(1)

(iv) Calculate the percentage by mass of copper in the brass.

(1)

(v) The manufacturers claim that the sample of brass contains 44.2 % copper by mass. Determine the percentage error in the result.

(1)

(c) With reference to its metallic structure, describe how brass conducts electricity.

Answers:

1. D
2. B
3. D
4. C
5. B
6. B
7. D
8. A
9. C
10. D
11. C_5H_{10}
12. 144 g
13. 4.0 g
14. 2.00 mol/L^{-1}
15. 72.9 L
16. a) $2\ Al(OH)_{3(s)} + 3\ H_2SO_{4(aq)} \rightarrow Al_2(SO_4)_{3(aq)} + 6\ H_2O_{(l)}$, LR = H_2SO_4 b) 68.4 g c) 15.6 g
17. a) $P_4 + 10\ Cl_2 \rightarrow 4\ PCl_5$, LR = Cl_2 b) 4.99 g of PCl_5 c) 83.4%
18. 16.7 mL
19. Xe
20. 2.34 L

IB Markscheme

1. empirical formula = CN;

Working must be shown to get point.

$M_r = 51.9$ (g mol^{-1});

:N≡≡≡C—C≡≡≡N:; 3

2.

C	N	O	H
$\frac{20.2}{12.01}$	$\frac{11.4}{14.01}$	$\frac{65.9}{16.00}$	$\frac{2.50}{1.01}$
= 1.68	= 0.814	= 4.12	= 2.48 ;
$\frac{1.68}{0.814} = 2$	$\frac{0.814}{0.814} = 1$	$\frac{4.12}{0.814} = 5$	$\frac{2.48}{0.814} = 3$;

$C_2NO_5H_3$;

No penalty for use of 12, 1 and/or 14.

*Award **[1 max]** if the empirical formula is correct, but no working shown.* 3

3. (a) 0.600 mol $Al(OH)_3$ ≡ (1.5)(0.600) mol H_2SO_4/0.900 mol H_2SO_4 needed, but only 0.600 mol used;
H_2SO_4 limiting reactant; 2

Some working must be shown in order to score the second point.

(b) 0.200 mol $Al_2(SO_4)_3$;
68.4(g); 2

Penalize incorrect units.

(c) 0.200 mol; 1

Use ECF from (a).

(d) A Brønsted-Lowry acid is a proton/H^+ donor;
A Lewis base is an electron-pair donor; 2

(e) H_2CO_3 and carbonic acid / CH_3COOH and ethanoic acid; 1

Accept any other weak acid and correct formula.

4. (a) (i) *Copper:*
0 to +2 / increases by 2 / +2 / 2+;
Allow zero/nought for 0.

Nitrogen:
+5 to +4 / decreases by 1 / –1 / 1–;
Penalize missing + sign or incorrect notation such as 2+, 2^+ or II, once only. 2

(ii) nitric acid/HNO_3 / NO_3^-/nitrate;
Allow nitrogen from nitric acid/nitrate but not just nitrogen. 1

(b) (i) 0.100×0.0285;
2.85×10^{-3} (mol);
*Award **[2]** for correct final answer.* 2

(ii) 2.85×10^{-3} (mol); 1

(iii) $(63.55 \times 2.85 \times 10^{-3}) = 0.181$ g;
Allow 63.5. 1

(iv) $\left(\frac{0.181}{0.456} \times 100 =\right)$ 39.7 % 1

(v) $\left(\frac{44.2 - 39.7}{44.2} \times 100 =\right)$ 10/10.2 %;
Allow 11.3 % i.e. percentage obtained in (iv) is used to divide instead of 44.2 %. 1

(c) *Brass has:*
delocalized electrons / sea of mobile electrons / sea of electrons
free to move;
No mark for just "mobile electrons". 1

Questions were taken and modified from savitapall.com, chemteam.info and IB Question Bank Chemistry – 3rd edition