CHEM111 UNIT 1 – MOLES, FORMULAE AND EQUATIONS
QUESTIONS

Lesson 1

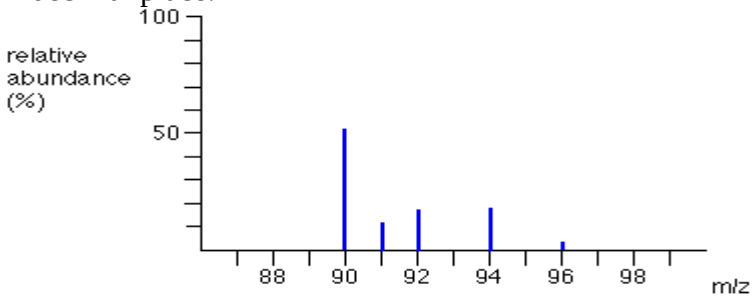
1. (a) Deduce the number of protons, neutrons and electrons in the following species:
(i) $^{37}Cl^{-}$
(ii) $^{1}H^{+}$
(iii) $^{45}Sc^{3+}$

(b) Write symbols for the following species:
(i) 8 protons, 8 neutrons, 10 electrons
(ii) 82 protons, 126 neutrons, 80 electrons
(iii) 1 proton, 2 neutrons, 1 electron

2. (a) Define the terms relative atomic mass and relative isotopic mass; explain why ^{9}Be and ^{9}B have slightly different masses

(b) Deduce the relative atomic mass of silicon to 2 decimal places, given that it has the following isotopes: ^{28}Si 92.21%, ^{29}Si 4.70%, ^{30}Si 3.09%

(c) Use the mass spectrum of zirconium below to deduce the relative atomic mass of zirconium to 1 decimal place:



(d) Most argon atoms have a mass number 40. How many neutrons does this isotope have? The relative isotopic mass of this isotope is 39.961, but the relative atomic mass of argon is 39.948. What can you deduce about the other isotopes of argon?

3. State and explain the five processes taking place in a mass spectrometer

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Lesson 2

4. (a) Classify the following substances as: A – giant ionic; B – giant metallic; C – simple molecular; D – simple atomic; E – giant covalent

(i) silicon dioxide
(ii) ammonia
(iii) potassium
(iv) magnesium chloride
(v) chlorine
(vi) water
(vii) copper sulphate
(viii) neon
(ix) graphite

(b) Deduce the unit formula for the following compounds:

(i) sodium oxide
(ii) magnesium oxide
(iii) calcium iodide
(iv) potassium sulphide
(v) magnesium sulphate
(vi) ammonium nitrate
(vii) calcium carbonate
(viii) aluminium oxide
(ix) strontium hydroxide
(x) ammonium sulphate

(c) State the molecular formula of the following molecules:

(i) water
(ii) ammonia
(iii) carbon dioxide
(iv) carbon monoxide
(v) chlorine

(d) (i) A compound containing 85.71% C and 14.29% H has a relative molecular mass of 56. Find its molecular formula.

(ii) Analysis of a hydrocarbon showed that 7.8 g of the hydrocarbon contained 0.6 g of hydrogen and that the relative molecular mass was 78. Find the molecular formula of the hydrocarbon.

(iii) An ionic compound is analysed and found to contain 48.4% oxygen, 24.3% sulphur, 21.2% nitrogen and 6.1% hydrogen. Calculate its empirical formula and deduce its unit formula.

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Lesson 3

5. (a) If you have 2.5×10^{21} atoms of magnesium, how many moles of magnesium do you have?
(b) If you have 0.25 moles of carbon dioxide, how many molecules of carbon dioxide do you have?

6. (a) Deduce the relative masses of:
(i) CO_2
(ii) Na_2CO_3
(iii) $MgCl_2$
(iv) CH_4
(v) $C_{12}H_{22}O_{11}$
(vi) $Mg(OH)_2$
(vii) $Al_2(SO_4)_3$
(b) In each case, indicate whether your answer is a relative formula mass or a relative molecular mass

7. (a) Calculate the number of moles present in:
(i) 2.5 g of O_2
(ii) 40 cm^3 of 0.2 $moldm^{-3}$ HNO_3
(b) Calculate the molarity and the mass concentration of an aqueous solution containing:
(i) 0.002 moles of H_2SO_4 in 16.5 cm^3
(ii) 0.1 moles of NH_3 in 50 cm^3
(iii) 8 g of NaOH in 250 cm^3
(c) What mass of $C_6H_{12}O_6$ should be added to a 250 cm^3 volumetric flask to make a 0.10 $moldm^{-3}$ solution when the flask is filled to its mark with water?
(d) What volume of 2.0 $moldm^{-3}$ hydrogen peroxide should be added to a 100 cm^3 volumetric flask to make a 0.050 $moldm^{-3}$ solution when the flask is filled to its mark with water?
(e) Concentrated HCl contains 36% HCl by mass (the rest is water). What mass of concentrated HCl should be added to a 250 cm^3 volumetric flask to make a 0.10 $moldm^{-3}$ solution when the flask is filled to its mark with water?

8. (a) According to the ideal gas equation, $PV = nRT$ ($R = 8.31\ Jmol^{-1}K^{-1}$)
Use the ideal gas equation to show that the **molar gas volume** at room temperature (298 K) and standard atmospheric pressure (101.3 kPa) is 24.4 dm^3
(b) Assuming room temperature and standard atmospheric pressure, calculate:
(i) the number of moles in 4.88 dm^3 of O_2
(ii) the volume occupied by 20 g of NO_2
(iii) the mass of 200 cm^3 of N_2

9. Deduce which sample (A, B or C) contains the most ammonia (NH_3):
Sample A contains 2.0 g of NH_3
Sample B contains 50 cm^3 of a 2 $moldm^{-3}$ aqueous solution of NH_3
Sample C contains 2.8 dm^3 of NH_3 at room temperature and standard atmospheric pressure

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Lesson 4

10. (a) Deduce the apparatus errors in the following measurements:
- (i) mass using a 2 dp mass balance
- (ii) temperature change using a thermometer with graduation marks every 1°C
- (iii) titre volume using a typical burette
- (iv) volume of solution using a measuring cylinder with graduation marks every 1 cm^3

(b) Deduce the percentage errors in the following measurements using the apparatus from Q11a unless otherwise stated:
- (i) A mass of 2.34 g
- (ii) A temperature change 6.5 ^{o}C
- (iii) A titre volume of 22.35 cm^3
- (iv) A volume of 25 cm^3 measured using a measuring cylinder
- (v) A volume of 25.0 cm^3 measured using a pipette with apparatus error 0.05 cm^3
- (vii) A volume of 250 cm^3 measured using a volumetric flask with apparatus error 0.2 cm^3

(c) Arrange the seven measurements in Q11b in order of increasing accuracy (ie from least accurate to most accurate)

(d) A student uses the measurements of 2.34 g, 6.5 ^{o}C and 25 cm^3 (using the measuring cylinder) to calculate an enthalpy change. Deduce the total percentage apparatus error in the answer.

(e) A student uses measurements of 2.34 g, 250 cm^3 (using the volumetric flask), 25.0 cm^3 (using the pipette) and the titre volume of 22.35 cm^3 to calculate a molar mass. Deduce the total percentage apparatus error in the answer.

11. (a) What is the difference between accuracy and precision?

(b) Explain the range of possible values represented by the following measurements:
- (i) 21 cm^3
- (ii) 21.0 cm^3
- (iii) 21.00 cm^3

(c) A student gets a calculator value of 0.02576281 $moldm^{-3}$ when calculating a concentration. The measurements used in the calculation created a total apparatus error of 2.1%. Express the concentration to a suitable number of significant figures.

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Lesson 5

12. Consider the combustion equation: $C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$

(a) How many moles of oxygen gas are required for the complete combustion of 0.2 moles of pentane (C_5H_{12})?

(b) How many moles of carbon dioxide are produced during the complete combustion of 0.2 moles of pentane?

(c) How many moles of water are produced during the complete combustion of 0.2 moles of pentane?

(d) 0.15 moles of pentane are mixed with 0.80 moles of oxygen and allowed to react completely.

(i) Which is the limiting reactant?

(ii) Which reactant is in excess and how many moles of it will be left after the reaction?

(iii) How many moles of carbon dioxide will be produced?

(iv) How many moles of water will be produced?

(v) If all reactants and products are in the gaseous state, what is the total number of gas moles remaining after the reaction is complete?

13. 0.52 g of sodium was added to 100 cm^3 of water and the following reaction took place:
$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$
Calculate:

(a) The volume of hydrogen evolved at 298 K and 100 kPa

(b) The concentration of the sodium hydroxide solution produced, assuming the volume of water does not change.

14. 0.10 g of magnesium was dissolved in 5.0 cm^3 of 2.0 $moldm^{-3}$ hydrochloric acid. The following reaction takes place: $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

(a) Deduce which of the two reactants is in excess.

(b) Hence calculate the volume of hydrogen gas produced (the molar gas volume under the conditions of the experiment was 24.4 dm^3)

15. Ethanol can be produced commercially either by the fermentation of glucose or by the hydration of ethene:
Fermentation: $C_6H_{12}O_6 \rightarrow 2C_2H_6O + 2CO_2$
Hydration: $C_2H_4 + H_2O \rightarrow C_2H_6O$

(a) Calculate the percentage atom economy of both reactions. Suggest how the percentage atom economy of the fermentation process could be improved.

(b) 100 g of glucose was fermented and 45 g of ethanol was obtained. Calculate the percentage yield of ethanol in this experiment.

(c) 100 g of ethene was hydrated in excess steam and 80 g of ethanol was obtained. Calculate the percentage yield of ethanol in this experiment.

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Lesson 6

16. Classify the following substances as acids, bases or salts:

(a) HCl
(b) $Ca(OH)_2$
(c) $MgCO_3$
(d) Na_2SO_4
(e) HNO_3
(f) BaO
(g) H_2SO_4
(h) $MgCl_2$
(i) Na_2CO_3
(j) NH_3

17. Write balanced symbol equations for the following reactions:

(a) sulphuric acid and sodium hydroxide
(b) nitric acid and calcium carbonate
(c) hydrochloric acid and magnesium oxide
(d) nitric acid and ammonia
(e) hydrochloric acid and potassium carbonate
(f) sulphuric acid and ammonia

18. (a) Give the formula of all three salts formed when H_3PO_4 reacts with NaOH.
(b) Give the equation for the most likely reaction when H_3PO_4 is mixed with NaOH in a 1:2 ratio
(c) Write an equation for the reaction occurring when aqueous carbon dioxide reacts with HCl
  (i) in a 1:1 ratio
  (ii) in a 1:2 ratio
(d) Write an equation for the reaction occurring when $NaHCO_3$ reacts with:
  (i) HCl
  (ii) NaOH
  (iii) Itself

19. Explain the meaning of the terms “strong acid”, “weak acid”, “strong base” and “weak base”. Give an example of each, writing an equation to show how each reacts with water.

20. Explain what is meant by the terms “acidic solution”, “alkaline solution” and “neutral solution”.

21. (a) Calculate the pH of the following solutions:
  (i) 0.015 $moldm^{-3}$ HCl
  (ii) 6.0 $moldm^{-3}$ HNO_3
  (iii) 0.20 $moldm^{-3}$ H_2SO_4
  (iv) The mixture formed when 10 cm^3 of 0.1 $moldm^{-3}$ NaOH is added to 25 cm^3 of 0.1 $moldm^{-3}$ HCl
(b) Calculate the molarity of the following solutions:
  (i) A solution of HNO_3 with a pH of 2.5
  (ii) A solution of H_2SO_4 with a pH of 0.5