1.3AB Reacting Masses and Volumes
Molarity and Titration Calculations

Past Exam Questions (Paper 1, 2)

1. *[1 mark]*

What will be the concentration of sulfate ions in $mol\,dm^{-3}$ when 0.20 mol of $KAl(SO_4)_2$ is dissolved in water to give 100 cm^3 of aqueous solution?

A. 0.2

B. 1.0

C. 2.0

D. 4.0

2. *[1 mark]*

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

A. 2.4

B. 3.0

C. 4.0

D. 5.6

3. *[1 mark]*

On analysis, a compound with molar mass 60 $g\,mol^{-1}$ was found to contain 12 g of carbon, 2 g of hydrogen and 16 g of oxygen. What is the molecular formula of the compound?

A. CH_2O

B. CH_4O

C. C_2H_4O

D. $C_2H_4O_2$

4. *[1 mark]*

Equal masses of the metals Na, Mg, Ca and Ag are added to separate samples of excess HCl (aq). Which metal produces the greatest total volume of $H_2(g)$?

A. Na

B. Mg

C. Ca

D. Ag

5. *[1 mark]*

8.5 g of NH_3 are dissolved in H_2O to prepare a 500 cm^3 solution. Which statements are correct?

I. NH_3 is the solute and H_2O is the solution

II. The concentration of the solution is 17 $g\ dm^{-3}$

III. $[NH_3] = 1.0\ mol\ dm^{-3}$

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

6. *[1 mark]*

What is the amount, in moles, of sulfate ions in 100 cm^3 of 0.020 $mol\ dm^{-3}$ $FeSO_4(aq)$?

A. 2.0×10^{-3}

B. 2.0×10^{-2}

C. 2.0×10^{-1}

D. 2.0

7. *[1 mark]*

1.7 g of $NaNO_3 (M_r = 85)$ is dissolved in water to prepare 0. 20 dm^3 of solution. What is the concentration of the resulting solution in $mol\,dm^{-3}$?

A. 0.01

B. 0.1

C. 0.2

D. 1.0

8. *[1 mark]*

At 25 °C, 200 cm^3 of 1. 0 $mol\,dm^{-3}$ nitric acid is added to 5.0 g of magnesium powder. If the experiment is repeated using the same mass of magnesium powder, which conditions will result in the same initial reaction rate?

	Volume of HNO_3 / cm^3	Concentration of HNO_3 / mol dm^{-3}	Temperature / °C
A.	200	2.0	25
B.	200	1.0	50
C.	100	2.0	25
D.	100	1.0	25

9. *[1 mark]*

Chloroethene, C_2H_3Cl, reacts with oxygen according to the equation below.

$$2C_2H_3Cl(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(g) + 2HCl(g)$$

What is the amount, in mol, of H_2O produced when 10.0 mol of C_2H_3Cl and 10.0 mol of O_2 are mixed together, and the above reaction goes to completion?

A. 4.00

B. 8.00

C. 10.0

D. 20.0

10. *[1 mark]*

What is the concentration of NaCl, in $mol\,dm^{-3}$, when 10. 0 cm^3 of 0. 200 $mol\,dm^{-3}$ NaCl solution is added to 30. 0 cm^3 of 0. 600 $mol\,dm^{-3}$ NaCl solution?

A. 0.450

B. 0.300

C. 0.500

D. 0.800

11. *[1 mark]*

What mass, in g, of hydrogen is formed when 3 mol of aluminium react with excess hydrochloric acid according to the following equation?

$$2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$$

A. 3.0

B. 4.5

C. 6.0

D. 9.0

12. *[1 mark]*

The equation for the reduction of iron(III) oxide is:

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$$

What mass of carbon dioxide, in g, is produced by the complete reduction of 80 g of iron(III) oxide?

A. 44

B. 66

C. 88

D. 132

13. *[1 mark]*

7.102 g of Na_2SO_4 ($M = 142.04\ g\ mol^{-1}$) is dissolved in water to prepare $0.5000\ dm^3$ of solution. What is the concentration of Na_2SO_4 in $mol\ dm^{-3}$?

A. 2.500×10^{-2}

B. 1.000×10^{-1}

C. 1.000×10

D. 1.000×10^{2}

14. *[1 mark]*

When 50 cm^3 of a hydrocarbon, C_xH_y, was burned in excess oxygen, 200 cm^3 of carbon dioxide and 250 cm^3 of steam were produced (all volumes were measured under the same conditions). What is the molecular formula of the hydrocarbon?

A. C_2H_4

B. C_3H_8

C. C_4H_8

D. C_4H_{10}

15. *[1 mark]*

What mass of carbon dioxide, CO_2(g), in g, is produced when 5.0 g of calcium carbonate, $CaCO_3$(s),reacts completely with hydrochloric acid, HCl(aq)?

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

A. 0.050

B. 2.2

C. 4.4

D. 5.0

16. *[1 mark]*

7.102 g of Na_2SO_4 (M = 142.04 g mol^{-1}) is dissolved in water to prepare 0.5000 dm^3 of solution. What is the concentration of Na_2SO_4 in $mol\,dm^{-3}$?

A. 2.500×10^{-2}

B. 1.000×10^{-1}

C. 1.000×10

D. 1.000×10^{2}

17. *[1 mark]*

0.040 mol of $(NH_4)_2Ni\,(SO_4)_2 \bullet 6H_2O$ is dissolved in water to give 200 cm^3 of aqueous solution. What is the concentration, in $mol\,dm^{-3}$, of ammonium ions?

A. 0.00040

B. 0.0080

C. 0.20

D. 0.40

18. *[1 mark]*

100.0 cm^3 of a 0.50 $mol\,dm^{-3}$ solution of $BaCl_2$ is added to 50.0 cm^3 of a 0.10 $mol\,dm^{-3}$ solution of Na_2SO_4. A precipitate of $BaSO_4$ is formed according to the equation below.

$$BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaCl(aq)$$

What is the amount, in mol, of $BaSO_4$ produced?

A. 0.0050

B. 0.010

C. 0.050

D. 0.10

19. *[1 mark]*

Which solution contains the biggest amount, in mol, of chloride ions?

A. 20 cm^3 of 0.50 $mol\,dm^{-3} NH_4Cl$

B. 60 cm^3 of 0.20 $mol\,dm^{-3} MgCl_2$

C. 70 cm^3 of 0.30 $mol\,dm^{-3} NaCl$

D. 100 cm^3 of 0.30 $mol\,dm^{-3} ClCH_2COOH$

20. *[1 mark]*

4.0 g of solid sodium hydroxide is added to 0.10 dm^3 of 1.0 $mol\ dm^{-3}$ aqueous sulfuric acid.

$$2NaOH(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

Which statement is correct?

A. Neither reactant is in excess.

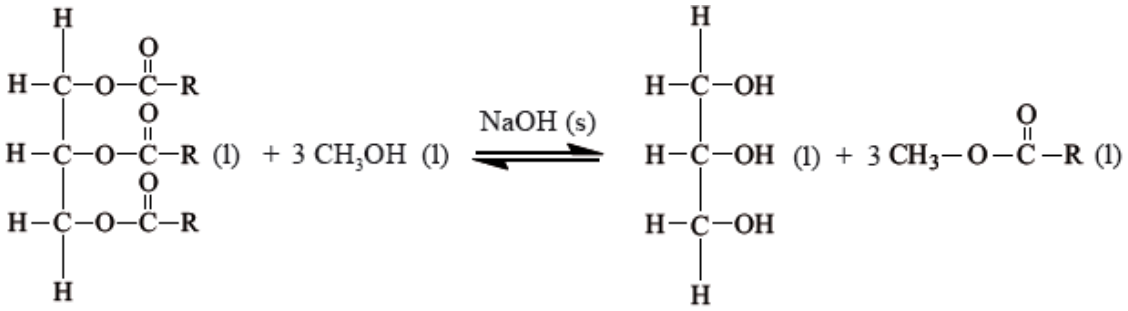
B. 0.10 mol Na_2SO_4 is formed.

C. Excess H_2SO_4 remains in solution.

D. Excess NaOH remains in solution.

21a. *[3 marks]*

Biodiesel makes use of plants' ability to fix atmospheric carbon by photosynthesis. Many companies and individuals are now using biodiesel as a fuel in order to reduce their carbon footprint. Biodiesel can be synthesized from vegetable oil according to the following reaction.



vegetable oil methanol glycerol biodiesel

For part of her extended essay investigation into the efficiency of the process, a student reacted a pure sample of a vegetable oil (where $R = C_{17}H_{33}$) with methanol. The raw data recorded for the reaction is below.

$$Mass\ of\ oil = 1013.0\ g\ Mass\ of\ sodium\ hydroxide = 3.5\ g\ Mass\ of\ biodiesel\ produced = 811.0\ g$$

$$Mass\ of\ methanol = 200.0\ g$$

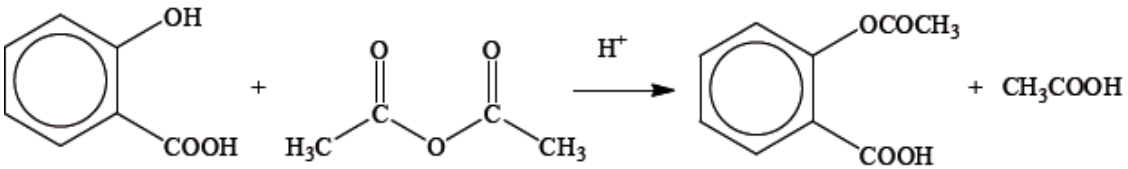
The relative molecular mass of the oil used by the student is 885.6. Calculate the amount (in moles) of the oil and the methanol used, and hence the amount (in moles) of excess methanol.

21b. *[2 marks]*

Calculate the percentage yield of biodiesel obtained in this process.

22a. *[2 marks]*

Aspirin, one of the most widely used drugs in the world, can be prepared according to the equation given below.



salicylic acid ethanoic anhydride ***aspirin*** ethanoic acid

A student reacted some salicylic acid with excess ethanoic anhydride. Impure solid aspirin was obtained by filtering the reaction mixture. Pure aspirin was obtained by recrystallization. The following table shows the data recorded by the student.

Mass of salicylic acid used	3.15 ± 0.02 g
Mass of pure aspirin obtained	2.50 ± 0.02 g

Determine the amount, in mol, of salicylic acid, $C_6H_4(OH)COOH$, used.

22b. *[2 marks]*

Calculate the theoretical yield, in g, of aspirin, $C_6H_4(OCOCH_3)COOH$.

22c. *[1 mark]*

Determine the percentage yield of pure aspirin.

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22d. *[2 marks]*

State the number of significant figures associated with the mass of pure aspirin obtained, and calculate the percentage uncertainty associated with this mass.

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22e. *[1 mark]*

Another student repeated the experiment and obtained an experimental yield of 150%. The teacher checked the calculations and found no errors. Comment on the result.

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23. *[2 marks]*

The Haber process enables the large-scale production of ammonia needed to make fertilizers. A student decided to investigate the reactions of the two acids with separate samples of 0. 20 $mol\,dm^{-3}$ sodium hydroxide solution.

(i) Calculate the volume of the sodium hydroxide solution required to react exactly with a 15. 0 cm^3 solution of 0. 10 $mol\,dm^{-3}$ nitric acid.

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24. *[11 marks]*

The percentage by mass of calcium carbonate in eggshell was determined by adding excess hydrochloric acid to ensure that all the calcium carbonate had reacted. The excess acid left was then titrated with aqueous sodium hydroxide.

(a) A student added 27. 20 cm^3 of 0. 200 $mol\,dm^{-3}$ HCl to 0.188 g of eggshell. Calculate the amount, in mol, of HCl added.

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(b) The excess acid requires 23. 80 cm^3 of 0. 100 $mol\,dm^{-3}$ NaOH for neutralization. Calculate the amount, in mol, of acid that is in excess.

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(c) Determine the amount, in mol, of HCl that reacted with the calcium carbonate in the eggshell.

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(d) State the equation for the reaction of HCl with the calcium carbonate in the eggshell.

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(e) Determine the amount, in mol, of calcium carbonate in the sample of the eggshell.

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(f) Calculate the mass **and** the percentage by mass of calcium carbonate in the eggshell sample.

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(g) Deduce **one** assumption made in arriving at the percentage of calcium carbonate in the eggshell sample.

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25a. *[6 marks]*

Two groups of students (Group A and Group B) carried out a project* on the chemistry of some group 7 elements (the halogens) and their compounds.

** Adapted from J Derek Woollins, (2009), Inorganic Experiments and Open University, (2008), Exploring the Molecular World.*

In the first part of the project, the two groups had a sample of iodine monochloride (a corrosive brown liquid) prepared for them by their teacher using the following reaction.

$$I_2(s) + Cl_2(g) \rightarrow 2ICl(l)$$

The following data were recorded.

Mass of I_2(s)	10.00 g
Mass of Cl_2(g)	2.24 g
Mass of ICl (l) obtained	8.60 g

(i) State the number of significant figures for the masses of $I_2(s)$ and ICl(l).

$I_2(s)$:

ICl (l):

(ii) The iodine used in the reaction was in excess. Determine the theoretical yield, in g, of ICl(l).

(iii) Calculate the percentage yield of ICl(l).

25b. *[6 marks]*

The students reacted ICl(l) with CsBr(s) to form a yellow solid, $CsICl_2(s)$, as one of the products. $CsICl_2(s)$ has been found to produce very pure CsCl(s) which is used in cancer treatment.

To confirm the composition of the yellow solid, Group A determined the amount of iodine in 0.2015 g of $CsICl_2(s)$ by titrating it with 0. 0500 $mol\,dm^{-3}$ $Na_2S_2O_3(aq)$. The following data were recorded for the titration.

Mass of $CsICl_2$(s) taken (in g ± 0.0001)	0.2015
Initial burette reading of 0.0500 mol dm^{-3} $Na_2S_2O_3$(aq) (in cm^3 ± 0.05)	1.05
Final burette reading of 0.0500 mol dm^{-3} $Na_2S_2O_3$(aq) (in cm^3 ± 0.05)	25.25

(i) Calculate the percentage of iodine by mass in $CsICl_2(s)$, correct to **three** significant figures.

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(ii) State the volume, in cm^3, of 0. 0500 $mol\,dm^{-3}$ $Na_2S_2O_3(aq)$ used in the titration.

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(iii) Determine the amount, in mol, of 0. 0500 $mol\,dm^{-3}$ $Na_2S_2O_3(aq)$ added in the titration.

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(iv) The overall reaction taking place during the titration is:

$$CsICl(s) + 2Na_2S_2O_3(aq) \rightarrow NaCl(aq) + Na_2S_4O_6(aq) + CsCl(aq) + NaI(aq)$$

Calculate the amount, in mol, of iodine atoms, I, present in the sample of $CsICl_2(s)$.

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(v) Calculate the mass of iodine, in g, present in the sample of $CsICl_2$

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(vi) Determine the percentage by mass of iodine in the sample of $CsICl_2(s)$, correct to **three** significant figures, using your answer from (v).

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