Questions

1 Epsom salts (magnesium sulfate) are commonly used as bath salts. However, the anhydrous form of the salt is a drying agent. To determine the water of hydration of Epsom salts, a 2.50 g sample of the salt was placed in a porcelain evaporating dish and gently heated over a Bunsen burner flame until no further changes were observed. Table 8 shows the results.

Description	Mass/g
mass of evaporating basin	24.10
mass of evaporating basin + $MgSO_4 \cdot xH_2O$	26.60
mass of evaporating basin after heating	25.32

▲ Table 8

a) Calculate the mass, in g, of water evaporated from the sample.

b) Calculate the amount amount, in mol, of H_2O.

c) Calculate the mass, in g, of $MgSO_4$.

d) Calculate the amount, in mol, of $MgSO_4$.

e) Calculate the ratio of amount of $MgSO_4$: amount of H_2O and deduce the value of x.

f) State the formula of the hydrated salt.

2 The value of x in $Fe(NH_4)_2(SO_4)_2 \cdot xH_2O$ can be found by determining the amount in mol of sulfate in the compound. A 0.982 g sample was dissolved in water and excess $BaCl_2(aq)$ was added. The precipitate of $BaSO_4$ was separated and dried and found to weigh 1.17 g.

a) Calculate the amount, in mol, of $BaSO_4$ in the 1.17 g of precipitate. [2]

b) Calculate the amount, in mol, of sulfate in the 0.982 g sample of $Fe(NH_4)_2(SO_4)_2 \cdot xH_2O$. [1]

c) Calculate the amount, in mol, of iron in the 0.982 g sample of $Fe(NH_4)_2(SO_4)_2 \cdot xH_2O$. [1]

d) Determine the mass, in g, of the following present in the 0.982 g sample of $Fe(NH_4)_2(SO_4)_2 \cdot xH_2O$:

(i) iron (ii) ammonium (iii) sulfate. [3]

e) Use your answer from part (d) to determine the amount in mol of water present in the 0.982 g sample of $Fe(NH_4)_2(SO_4)_2 \cdot xH_2O$. [2]

f) Determine the amount, in mol, of $Fe(NH_4)_2(SO_4)_2 \cdot xH_2O$ and hence the value of x. [2]

IB, May 2008

3 The equation for a reaction occurring in the synthesis of methanol is:

$$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$$

What is the maximum amount of methanol that can be formed from 2 mol of carbon dioxide and 3 mol of hydrogen?

A. 1 mol

B. 2 mol

C. 3 mol

D. 5 mol [1]

IB, May 2006

4 Calcium carbonate decomposes on heating as shown below.

$$CaCO_3 \rightarrow CaO + CO_2$$

When 50 g of calcium carbonate are decomposed, 7 g of calcium oxide are formed. What is the percentage yield of calcium oxide?

A. 7%

B. 25%

C. 50%

D. 75% [1]

IB, November 2006

5 Ethyne, C_2H_2, reacts with oxygen according to the equation below. What volume of oxygen (in dm^3) reacts with 0.40 dm^3 of C_2H_2?

$$2C_2H_2(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(g)$$

A. 0.40

B. 0.80

C. 1.0

D. 2.0 [1]

IB, November 2007

6 A fixed mass of an ideal gas has a volume of 800 cm^3 under certain conditions. The pressure (in kPa) and temperature (in K) are both doubled. What is the volume of the gas after these changes with other conditions remaining the same?

A. 200 cm^3

B. 800 cm^3

C. 1600 cm^3

D. 3200 cm^3 [1]

IB, May 2005

7 Assuming complete reaction, what volume of 0.200 mol dm^{-3} potassium hydroxide solution, KOH(aq) is required to neutralize 25.0 cm^3 of 0.200 mol dm^{-3} aqueous sulfuric acid, $H_2SO_4(aq)$?

A. 12.5 cm^3

B. 25.0 cm^3

C. 50.0 cm^3

D. 75.0 cm^3 [1]

IB, May 2007

8 Copper metal may be produced by the reaction of copper(I) oxide and copper(I) sulfide according to the below equation. [1]

$2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$

A mixture of 10.0 kg of copper(I) oxide and 5.00 kg of copper(I) sulfide was heated until no further reaction occurred.

a) Determine the limiting reagent in this reaction, showing your working. [3]

b) Calculate the maximum mass of copper that could be obtained from these masses of reactants. [2]

IB, May 2006

9 An organic compound A contains 62.0% by mass of carbon, 24.1% by mass of nitrogen, the remainder being hydrogen.

a) Determine the percentage by mass of hydrogen and the empirical formula of A. [3]

b) Define the term relative molecular mass. [2]

c) The relative molecular mass of A is 116. Determine the molecular formula of A. [1]

IB, November 2006

10 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. Determine the empirical formula of A. Calculate the molar mass of the compound and determine its molecular structure. [3]

IB, specimen paper 2009

11 An oxide of copper was reduced in a stream of hydrogen. After heating, the stream of hydrogen gas was maintained until the apparatus had cooled. The following results were obtained.

Mass of empty dish = 13.80 g
Mass of dish and contents before heating = 21.75 g
Mass of dish and contents after heating and leaving to cool = 20.15 g

a) Explain why the stream of hydrogen gas was maintained until the apparatus cooled. [1]

b) Calculate the empirical formula of the oxide of copper using the data above, assuming complete reduction of the oxide. [3]

c) Write an equation for the reaction that occurred. [1]

d) State two changes that would be observed inside the tube as it was heated. [2]

IB, November 2004

12 0.502 g of an alkali metal sulfate is dissolved in water and excess barium chloride solution, $BaCl_2(aq)$ is added to precipitate all the sulfate ions as barium sulfate, $BaSO_4(s)$. The precipitate is filtered and dried and weighs 0.672 g.

a) Calculate the amount (in mol) of barium sulfate formed. [2]

b) Determine the amount (in mol) of the alkali metal sulfate present. [1]

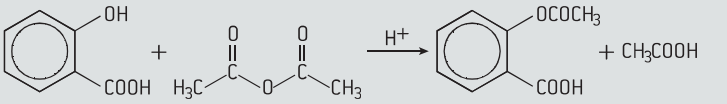
c) Determine the molar mass of the alkali metal sulfate and state its units. [2]

d) Deduce the identity of the alkali metal, showing your workings. [2]

e) Write an equation for the precipitation reaction, including state symbols. [2]

IB, May 2007

13 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. 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. Table 9 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

▲Table 9

i) Determine the amount, in mol, of salicylic acid, $C_6H_4(OH)COOH$, used. [2]

ii) Calculate the theoretical yield, in g, of aspirin, $C_6H_4(OCOCH_3)COOH$. [2]

iii) Determine the percentage yield of pure aspirin. [1]

iv) State the number of significant figures associated with the mass of pure aspirin obtained, and calculate the percentage uncertainty associated with this mass. [2]

v) 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. [1]

IB, May 2009

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

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		

▲Table 10

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]

IB, May 2010

End of topic questions (page 34)

1. a) $26.60 - 25.32 = 1.280$ g

b) $\frac{1.220}{18.02} = 0.06770$ mol

c) $25.32 - 24.10 = 1.220$ g

d) $\frac{1.22}{120.38} = 0.01013$ mol

e) 1:6.683

f) $MgSO_4.7H_2O$

2. a) $\frac{1.17}{233.4} = 5.01 \times 10^{-3}$ mol (5.02×10^{-3} mol also acceptable)

b) 5.01×10^{-3} mol (5.02×10^{-3} mol)

c) 2.50×10^{-3} mol (2.51×10^{-3} mol)

d) **(i)** Iron $55.85 \times 2.50 \times 10^{-3} = 0.140$ g

(ii) Ammonium $18.05 \times 5.01 \times 10^{-3} = 0.0904$ g

(iii) Sulfate $96.06 \times 5.01 \times 10^{-3} = 0.481$ g

e) $0.982\text{g} - 0.711\text{g} = 0.271$ g H_2O;
$\frac{0.271}{18.02} = 1.50 \times 10^{-2}$ mol

f) $\frac{0.711}{284.07} = 2.50 \times 10^{-3}$ mol; $\frac{1.50 \times 10^{-2}}{2.50 \times 10^{-3}} = 6$

3. A

4. B

5. C

6. B

7. C

8. a) $n(Cu_2O) = \frac{10.0 \times 10^3}{143.1} = 69.9$ mol

$n(Cu_2S) = \frac{5.00 \times 10^3}{159.16} = 31.4$ mol

Cu_2S is the limiting reagent

b) $n(Cu) = 6 \times n(Cu_2S) = 6 \times 31.4 = 188$ mol

$m(Cu) = 188 \times 63.55 = 11947$ g (11.9 kg);

9. a)

C	N	H
$\frac{62.0}{12.01} = 5.16$	$\frac{24.1}{14.01} = 1.72$	$\frac{13.9}{1.01} = 13.8$;

C_3NH_8;

b) the average mass of a molecule compared to 1/12 of (the mass of) one atom of ^{12}C which by definition is taken as 12 **or**

average mass of a molecule/mass of 1/12 of one atom of ^{12}C

c) $C_6N_2H_{16}$

10. empirical formula = CN

$M_r = 51.9$ g mol^{-1}

:N≡C—C≡N:

11. a) to prevent (re)oxidation of the copper

b) number of moles of oxygen $= \frac{1.60}{16.00} = 0.10$

number of moles of copper $= \frac{6.35}{63.55} = 0.10$

empirical formula = Cu (0.10) : O (0.10) = CuO

$\frac{6.35}{7.95} = 79.8\%$ $\frac{1.60}{7.95} = 20.2\%$

$\frac{70.8}{63.5} = 1.25$ $\frac{20.2}{16} = 1.29$

c) $H_2 + CuO \rightarrow Cu + H_2O$

d) (black copper oxide) solid turns red/brown; condensation/water vapour (on sides of test tube);

12. a) $M(BaSO_4) = 137.34 + 32.06 + 4 \times (16.00) = 233.40 \text{ g mol}^{-1}$

$n(BaSO_4) = \frac{0.672 \text{ g}}{233.40 \text{ g mol}^{-1}} = 0.00288 = 2.88 \times 10^{-3} \text{ mol}$

b) n(alkali metal sulfate) $= 0.00288 = 2.88 \times 10^{-3}$ mol

c) $M = \frac{m}{n} = \frac{0.502\text{g}}{0.00288 \text{ mol}} = 174.31$ units: g mol^{-1}

d) $2(A_r) + 32 + 4(16) = 174$, thus $A_r = 39$ or $A_r = \frac{(174 - (32 + (4 \times 16)}{2} = 39$; *Potassium* (*K*);

e) $K_2SO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + 2KCl(aq)$

13. A. (i) $M_r(C_7H_6O_3) = 138.13 \text{ g mol}^{-1}$

$n = \frac{3.15}{138.13} = 2.28 \times 10^{-2}$ mol

(ii) $M_r(C_9H_8O_4) = 180.17 \text{ g mol}^{-1}$

$m = 180.17 \times 2.28 \times 10^{-2} = 4.11\text{g}$

(iii) percentage yield $= \frac{2.50}{4.11} \times 100 = 60.8\ \%$;

(iv) 3; percentage uncertainty $= \frac{0.02}{2.50} \times 100 = 0.80\ \%$

(v) sample contaminated with ethanoic acid / aspirin not dry / impure sample;

14. B. (i) $0.100 \times 0.0285 = 2.85 \times 10^{-3}$ mol

(ii) 2.85×10^{-3} mol

(iii) $63.55 \times 2.85 \times 10^{-3} = 0.181$ g

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

(v) $\frac{44.2 - 39.7}{44.2} \times 100 = \frac{10}{10.2}\%$