TASK 1 – Writing formulas of ionic compounds

1	$AgBr$	2	Na_2CO_3	3	K_2O	4	Fe_2O_3	5	$CrCl_3$	6	$Ca(OH)_2$
7	$Al(NO_3)_3$	8	Na_2SO_4	9	PbO	10	Na_3PO_4	11	$Zn(HCO_3)_2$	12	$(NH_4)_2SO_4$
13	$Ga(OH)_3$	14	$SrSe$	15	$RaSO_4$	16	Na_3N				

TASK 2 – Writing formulas 1

1	PbO_2	2	Cu	3	Na	4	NH_4Cl	5	NH_3	6	S_8
7	H_2SO_4	8	Ne	9	SiO_2	10	Si	11	$Ba(OH)_2$	12	$SnCl_4$
13	$AgNO_3$	14	I_2	15	Ni	16	H_2S	17	TiO_2	18	Pb
19	$SrSO_4$	20	Li								

TASK 3 – Writing formulas 2

1	Ag_2CO_3	2	Au	3	PtF_2	4	HNO_3	5	NH_3	6	SiH_4
7	P_4	8	C	9	V_2O_5	10	$Co(OH)_2$	11	$Ba(OH)_2$	12	NH_3
13	HCl	14	F_2	15	Si	16	$Ca_3(PO_4)_2$	17	Rb	18	GeO_2
19	$MgAt_2$	20	NO								

TASK 4 – Writing balanced equations 1

1. a $Mg + 2\ HNO_3 \rightarrow Mg(NO_3)_2 + H_2$

   b $CuCl_2 + 2\ NaOH \rightarrow Cu(OH)_2 + 2\ NaCl$

   c $2\ SO_2 + O_2 \rightarrow 2\ SO_3$

   d $C_4H_{10} + 6\frac{1}{2}\ O_2 \rightarrow 4\ CO_2 + 5\ H_2O$ or $2\ C_4H_{10} + 13\ O_2 \rightarrow 8\ CO_2 + 10\ H_2O$

2. a $4\ Na + O_2 \rightarrow 2\ Na_2O$

   b $2\ Al + 3\ Cl_2 \rightarrow 2\ AlCl_3$

   c $Ca + 2\ HCl \rightarrow CaCl_2 + H_2$

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

TASK 5 – Writing balanced equations 2

1    $4 \, Al + 3 \, O_2 \rightarrow 2 \, Al_2O_3$

2    $C_6H_{14} + 9\frac{1}{2} \, O_2 \rightarrow 6 \, CO_2 + 7 \, H_2O$ or $2 \, C_6H_{14} + 19 \, O_2 \rightarrow 12 \, CO_2 + 14 \, H_2O$

3    $CH_3CH_2SH + 4\frac{1}{2} \, O_2 \rightarrow 2 \, CO_2 + SO_2 + 3 \, H_2O$ or $2 \, CH_3CH_2SH + 9 \, O_2 \rightarrow 4 \, CO_2 + 2 \, SO_2 + 6 \, H_2O$

4    $2 \, Li + 2 \, H_2O \rightarrow 2 \, LiOH + H_2$

5    $CaCO_3 + 2 \, HNO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2$

6    $Li_2CO_3 \rightarrow Li_2O + CO_2$

7    $NH_3 + HNO_3 \rightarrow NH_4NO_3$

8    $K_2O + H_2SO_4 \rightarrow K_2SO_4 + H_2O$

9    $Ca(OH)_2 + 2 \, HCl \rightarrow CaCl_2 + 2 \, H_2O$

10    $3 \, Zn + 2 \, H_3PO_4 \rightarrow Zn_3(PO_4)_2 + 3 \, H_2$

11    $2 \, NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2 \, H_2O + 2 \, CO_2$

12    $2 \, KOH + H_2SO_4 \rightarrow K_2SO_4 + 2 \, H_2O$

TASK 6 – Ionic equations

1   HCl, $LiOH$, 1:1; H_2SO_4, $NaHCO_3$, 1:2; HNO_3, NH_3, 1:1; H_2SO_4, K_2CO_3, 1:1, HNO_3, $Sr(OH)_2$, 2:1

2   a $H^+ + OH^- \rightarrow H_2O$

     b $Ag^+ + I^- \rightarrow AgI$

     c $2 \, H^+ + CO_3^{2-} \rightarrow H_2O + CO_2$

     d $Ca^{2+} + 2 \, OH^- \rightarrow Ca(OH)_2$

     e $NH_3 + H^+ \rightarrow NH_4^+$

     f $H^+ + HCO_3^- \rightarrow H_2O + CO_2$

     g $Ca^{2+} + SO_4^{2-} \rightarrow CaSO_4$

     h $Pb^{2+} + 2 \, Cl^- \rightarrow PbCl_2$

     i $H^+ + OH^- \rightarrow H_2O$

TASK 7 – Significant figures & standard form

	a	b	c	d	e	f
1	345800	297000	0.0790	6.10	0.00156	0.01040
2	2350000 (3sf)	0.25 (2sf)	13.7	300 (2sf)	0.00198 (3sf)	0.00031 (2sf)
3	0.0015	0.00046	357500	534	1030000	0.00835
4	1.64×10^{-4}	5.24×10^{-2}	1.5×10^{-8}	3.45×10^{4}	6.2×10^{-1}	8.7×10^{7}
5	0.021 (2sf)	6.1×10^{-5} (2sf)	4.0×10^{8}	2400	0.0610	8.00×10^{-7} (3sf)

TASK 8 – Relative formula mass

1	38.0	2	55.8	3	98.1	4	102.0	5	58.3	6	213.0
7	132.1	8	123.5	9	169.9	10	80.0	11	249.5	12	24.3
13	32.0	14	102.9	15	78.1	16	174.3	17	71.0	18	399.9

TASK 9A – Moles

	a		b		c		d		e	
1	2.96		50.3		0.500		17100		0.000107	
2	355 g		20.4 g		1.08 g		0.264 g		85.8 g	
3	0.250		0.250		0.500					
4	0.0500		0.100		0.150					

5   176

6   a 1.6735×10^{-24} g   b 1.6726×10^{-24} g   c   3.025 g

TASK 9B – Avogadro number

1    $\frac{12.0}{6.022\ x\ 10^{23}}$ = 1.99 x 10^{-23} g

2   mol H_2O = $\frac{9.0}{18.0}$ = 0.5   number of molecules = 0.5 x 6.022 x 10^{23} = 3.011 x 10^{23}

3   mol N_2 = $\frac{42.0}{28.0}$ = 1.5   number of N atoms = 2 x 1.5 x 6.022 x 10^{23} = 1.81 x 10^{24}

TASK 10 – What equations mean

1   12 mol Na + 3 mol $O_2 \rightarrow$ 6 mol Na_2O;   0.1 mol Na + 0.025 mol $O_2 \rightarrow$ 0.05 mol Na_2O

2   5 mol Al + 7.5 mol $Cl_2 \rightarrow$ 5 mol $AlCl_3$;   0.1 mol Al + 0.15 mol $Cl_2 \rightarrow$ 0.1 mol $AlCl_3$

3   0.5 mol C_4H_{10} + 3.25 mol $O_2 \rightarrow$ 2 mol CO_2 + 2.5 mol H_2O;   20 mol C_4H_{10} + 130 mol $O_2 \rightarrow$ 80 mol CO_2 + 100 mol H_2O

4   0.5 mol NH_3 + 0.375 mol $O_2 \rightarrow$ 0.25 mol N_2 + 0.75 mol H_2O;   10 mol NH_3 + 7.5 mol $O_2 \rightarrow$ 5 mol N_2 + 15 mol H_2O
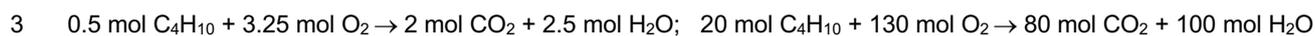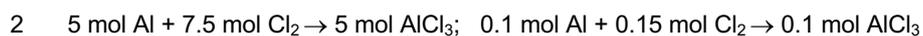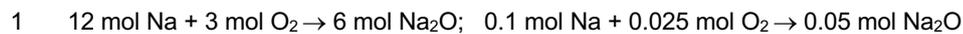
TASK 11 – Reacting mass calculations 1

1	1.01 g	2	126 g	3	120 g	4	253000 g	5	17.6 g	6	12.0 g
7	7	8	6	9	9780 g	10	1560000 g	11	0.00940 g	12	1.11 g
13	115 g	14	1650000 g	15	64.0 g	16	89.3 g				

1 Moles CuO = $\frac{40}{79.5}$ = 0.503

Moles H_2 = 0.503

Mass H_2 = 2.0 × 0.503 = 1.01 g   **1.01 g**

2 Moles Mg = $\frac{192}{24.3}$ = 7.901

Moles O_2 = 3.951

Mass O_2 = 32.0 × 3.951 = 126.4 g   **126 g**

3 Moles SO_2 = $\frac{96}{64.1}$ = 1.498

Moles SO_3 = 1.498

Mass SO_3 = 80.1 × 1.498 = 120 g   **120 g**

4 Moles Fe_2O_3 = $\frac{480000}{159.6}$ = 3007.5

Moles CO = 9023

Mass CO = 28.0 × 9023 = 253000 g   **253000 g**

5 Moles C_4H_8 = $\frac{5.6}{56.0}$ = 0.100

Moles CO_2 = 0.400

Mass CO_2 = 44.0 × 0.400 = 17.6 g   **17.6 g**

6 Moles H_2S = $\frac{8.5}{34.1}$ = 0.2493

Moles O_2 = 0.3739

Mass O_2 = 32.0 × 0.3739 = 12.0 g   **12.0 g**

7 Moles $MgSO_4$ = $\frac{2.40}{120.4}$ = 0.01993

Moles $MgSO_4 . n H_2O$ = 0.01993

$Mr = \frac{4.92}{0.01993} = 246.8$

$\underset{120.4 \quad 126.4}{MgSO_4 . n H_2O}$ $n = \frac{126.4}{18} = 7.02 \quad n = 7$

8

Moles $MgBr_2$ = $\dfrac{4.60}{184.1}$ = 0.02499

Moles $MgBr_2 \cdot xH_2O$ = 0.02499

M_r = $\dfrac{7.30}{0.02499}$ = 292.2

$\underline{MgBr_2} \cdot \underline{xH_2O}$ $n = \dfrac{108.1}{18}$ = 6.00 $n = 6$
184.1 108.1

9

Moles C_2H_5OH = $\dfrac{5000}{46.0}$ = 108.7

Moles $C_6H_{12}O_6$ = 54.35

Mass $C_6H_{12}O_6$ = 180.0 × 54.35 = 9780 g

10

Moles SO_2 = $\dfrac{1000000}{64.1}$ = 15600

Moles $CaCO_3$ = 15600

Mass $CaCO_3$ = 100.1 × 15600 = 1562000 g   1562000 g

11

moles K = $\dfrac{0.0078}{39.1}$ = 0.000199

moles K_2O = 0.00009974

mass K_2O = 94.2 × 0.00009974 = 0.00940 g   0.00940 g

12

Moles Al = $\dfrac{10.0}{27.0}$ = 0.3704

moles H_2 = 0.5556

mass H_2 = 2.0 × 0.5556 = 1.11 g   1.11 g

13

Moles O_2 = $\dfrac{40.0}{32.0}$ = 1.25

moles Na = 5.00

Mass Na = 23.1 × 5.00 = 115 g   115 g

14

Moles NH_3 = $\dfrac{2 \times 10^6}{17.0}$ = 117600

Moles N_2 = 58820

Mass N_2 = 28.0 × 58820 = 1650000 g   1650000 g

15

Moles H_2O_2 = $\dfrac{136}{34.0}$ = 4.00

Moles O_2 = 2.00

Mass O_2 = 32.0 × 2.00 = 64.0 g   64.0 g

16

Moles PbO = 0.400

Mass PbO = 223.2 × 0.400 = 89.3 g   89.3 g

TASK 12A – Limiting reagents 1

1		CaO	+	H_2O	$\rightarrow$	$Ca(OH)_2$		
	a)	2 mol		3 mol		**2 mol**		
	b)	10 mol		8 mol		**8 mol**		
	c)	0.40 mol		0.50 mol		**0.40 mol**		

2		2Ca	+	O_2	$\rightarrow$	2CaO		
	a)	2 mol		2 mol		**2 mol**		
	b)	10 mol		2 mol		**4 mol**		
	c)	0.50 mol		0.20 mol		**0.4 mol**		

3		2Fe	+	$3Cl_2$	$\rightarrow$	$2FeCl_3$		
	a)	3 mol		3 mol		**2 mol**		
	b)	12 mol		15 mol		**10 mol**		
	c)	20 mol		40 mol		**20 mol**		

4		$TiCl_4$	+	4Na	$\rightarrow$	Ti	+	4NaCl
	a)	4 mol		4 mol		**1 mol**		**4 mol**
	b)	2 mol		10 mol		**2 mol**		**8 mol**
	c)	0.5 mol		1 mol		**0.25 mol**		**1 mol**

5		C_2H_5OH	+	$3O_2$	$\rightarrow$	$2CO_2$	+	$3H_2O$
	a)	15 mol		30 mol		**20 mol**		**30 mol**
	b)	0.25 mol		1 mol		**0.5 mol**		**0.75 mol**
	c)	3 mol		6 mol		**4 mol**		**6 mol**

6		N_2	+	$3H_2$	$\rightarrow$	$2NH_3$		
	a)	3 mol		6 mol		**4 mol**		
	b)	0.5 mol		0.9 mol		**0.6 mol**		
	c)	6 mol		20 mol		**12 mol**		

7		4K	+	O_2	$\rightarrow$	$2K_2O$		
	a)	10 mol		2 mol		**4 mol**		
	b)	6 mol		4 mol		**3 mol**		
	c)	0.50 mol		0.20 mol		**0.25 mol**		

TASK 12B – Limiting reagents 2

1 **Moles of CaO** $= \dfrac{10.0}{56} = $ **0.179 mol**   **Moles of H₂O** $= \dfrac{10.0}{18} = $ **0.556 mol**

   0.179 mol of CaO reacts with 0.179 mol of H₂O, ∴ H₂O is in excess; CaO is limiting reagent

   moles of Ca(OH)₂ formed = 0.179 mol

   mass of Ca(OH)₂ = 74 x 0.179 = 13.2 g

2 **Moles of Mg** $= \dfrac{1.000}{24} = $ **0.0417 mol**   **Moles of Br₂** $= \dfrac{5.00}{160} = $ **0.03125 mol**

   0.03125 mol of Mg reacts with 0.03125 mol of Br₂, ∴ Mg is in excess; Br₂ is limiting reagent

   moles of MgBr₂ formed = 0.03125 mol

   mass of MgBr₂ = 184 x 0.03125 = 5.75 g

3 **Moles of CuO** $= \dfrac{2.00}{79.5} = $ **0.0252 mol**   **Moles of H₂** $= \dfrac{1.00}{2} = $ **0.500 mol**

   0.0252 mol of CuO reacts with 0.0252 mol of H₂, ∴ H₂ is in excess; CuO is limiting reagent

   moles of Cu formed = 0.0252 mol

   mass of Cu = 63.5 x 0.0252 = 1.60 g

4 **Moles of Na** $= \dfrac{2.30}{23} = $ **0.100 mol**   **Moles of F₂** $= \dfrac{2.85}{38} = $ **0.075 mol**

   0.100 mol of Na reacts with 0.050 mol of F₂, ∴ F₂ is in excess; Na is limiting reagent

   moles of NaF formed = 0.100 mol

   mass of NaF = 42 x 0.100 = 4.20 g

5 **Moles of Fe₂O₃** $= \dfrac{8.00}{160} = $ **0.050 mol**   **Moles of Al** $= \dfrac{2.16}{27} = $ **0.080 mol**

   0.040 mol of Fe₂O₃ reacts with 0.080 mol of Al, ∴ Fe₂O₃ is in excess; Al is limiting reagent

   moles of Fe formed = 0.080 mol

   mass of Fe = 56 x 0.080 = 4.48 g

6 **Moles of Al** $= \dfrac{13.5}{27} = $ **0.500 mol**   **Moles of Cl₂** $= \dfrac{42.6}{71} = $ **0.600 mol**

   0.400 mol of Al reacts with 0.600 mol of Cl₂, ∴ Al is in excess; Cl₂ is limiting reagent

   moles of AlCl₃ formed = 0.400 mol

   mass of AlCl₃ = 133.5 x 0.400 = 53.4 g

TASK 12C – Reacting mass calculations 2

1

Moles Fe = $\frac{5.00}{55.8}$ = 0.08961

Moles S = $\frac{5.00}{32.1}$ = 0.1558   XS

Moles FeS = 0.08961

mass FeS = 87.9 × 0.08961 = 7.88 g

2

Moles H_2SO_4 = $\frac{2000}{98.1}$ = 20.39

Moles NH_3 = $\frac{1000}{17.0}$ = 58.82   XS

Moles $(NH_4)_2SO_4$ = 20.39

mass $(NH_4)_2SO_4$ = 132.1 × 20.39 = **2690 g**

3

Moles NH_4Cl = $\frac{2000000}{53.5}$ = 37383   XS

Moles CaO = $\frac{5000000}{56.1}$ = 89.3

Moles NH_3 = 17825.3

Mass NH_3 = 17.0 × 17825.3 = **303000 g**

4

mol $TiCl_4$ = $\frac{500}{189.9}$ = 2.63 XS

mol Mg = $\frac{100}{24.3}$ = 4.12

∴ mol Ti = $\frac{4.12}{2}$ = 2.06

∴ mass Ti = 47.9 × 2.06 = 98.6 g

5

mol N_2 = $\frac{1000}{28.0}$ = 35.7

mol H_2 = $\frac{500}{2.0}$ = 250.0   XS

∴ mol NH_3 = 35.7 × 2 = 71.4

∴ mass NH_3 = 17.0 × 71.4 = 1210 g

6

mol SO_2 = $\frac{1000}{64.1}$ = 15.60

mol O_2 = $\frac{500}{32.0}$ = 15.63   XS

∴ mol SO_3 = 15.60

mass SO_3 = 80.1 × 15.60 = 1250 g

7

mol NH_3 = $\frac{100}{17.1}$ = 5.85   XS

mol NaOCl = $\frac{100}{74.5}$ = 1.34

∴ mol N_2H_4 = 1.34

mass N_2H_4 = 32.0 × 1.34 = 42.9 g

CHALLENGE 1

1    $NaHCO_3$ = 3.51 g, Na_2CO_3 6.49 g   2 $CaCO_3$ = 40.3%, $MgCO_3$ = 59.7%   3 C_4H_8 4   25.9%

1    $2 NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$

168.2 $\rightarrow$ 106.2 $\underbrace{\qquad}_{62.0}$
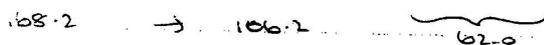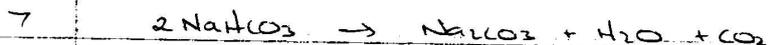
Mass lost = 1.292 g $1.292 \times \frac{168.2}{62} = 3.51$ g

$NaHCO_3$ = 3.51 g

Na_2CO_3 = 6.49 g

2    $CaCO_3 \rightarrow CaO + CO_2$ $MgCO_3 \rightarrow MgO + CO_2$

$\frac{x}{100.1}$ $\frac{10-x}{84.3}$

Moles CO_2 = 4.904/44.0 = 0.1115

$0.1115 = \frac{x}{100.1} + \frac{10-x}{84.3}$

$0.1115 = 0.00 x + 0.119 - 0.0119 x$

$0.00186 x = 0.0075$

$x = 4.03$ g

$CaCO_3$ = 40.3%

$MgCO_3$ = 59.7%

3    $C_nH_{2n} + \frac{3n}{2} O_2 \rightarrow n CO_2 + n H_2O$

mol $O_2 = \frac{192}{32.0} = 6$ mol

$\therefore \frac{3n}{2} = 6$ $\therefore n = 4$ $\rightarrow C_4H_8$

4   An epic challenge!   % $MgSO_4.7H_2O$ = 25.9%
     try it yourself —too good to give away!

TASK 13 – Percentage yield

1 a 120 g   b 74.9%   c reversible, product lost on isolation, other reactions take place

2 a 700000 g   b 92.3%   3 a 510 g   b 30.0%

4 a 25.2 g   b 79.4%   5 a 529 g   b 94.4%

6 a 330 g   b 90.8%   7 a 2.40 g   b 88.4%

1 a) moles SO_2 = $\frac{96}{64.1}$ = 1.50

moles SO_3 = 1.50

mass SO_3 = 1.50 × 80.1 = 120.2 g

b) % = $\frac{90}{120.15}$ × 100 = __74.9%__

c) • reversible

• product lost on isolation

• other reactions

2 a) moles Fe_2O_3 = $\frac{1000000}{159.6}$ 160.2 = 6242

moles Fe = 12484

mass Fe = 700,000 g

b) % = $\frac{650000}{700000}$ × 100 = __92.8%__ 92.3%

3 a) moles H_2 = $\frac{90}{2.0}$ = 45

moles NH_3 = 30

mass NH_3 = 30 × 17.0 = __510 g__

b) % = $\frac{153}{510}$ × 100 = __30%__

4 a) moles $TiCl_4$ = $\frac{100}{189.9}$ = 0.527

moles Ti = 0.527

mass Ti = __25.2 g__

b) % = $\frac{20}{25.2}$ × 100 = __79.4%__

5 a) moles Al_2O_3 = $\frac{1000}{102}$ = 9.80

moles Al = 19.61

mass Al = 529.4 g

b) % = $\frac{500}{529.4}$ × 100 = __94.4%__

6	a)	moles NH_3 = $\frac{85}{17.0}$ = 5
		moles $(NH_4)_2SO_4$ = 2.5
		mass $(NH_4)_2SO_4$ = 2.5 × 132.1 = 330.3 g
	b)	% = $\frac{300}{330.3}$ = 90.8%

7	moles $C_6H_{12}O$ = $\frac{0.85}{100}$ = 0.0085
	moles $C_2H_5N_4O_4$ = 0.0085
	mass = 282 × 0.0085 = 2.40 g
	% = $\frac{2.118}{2.40}$ × 100 = 88.4%

TASK 14 – Atom economy

1	39.3%	2	1.5%	3	45.8%	4	56.0%	5	100%	6	47.1%

7   a   320 g   b   87.5%   c   29.5%

     d   % yield compares the amount produced compared to the amount you should get, atom economy is the proportion of the mass of all the products that is the desired product

1

$2Na + Cl_2$

$2(23)$ 71.0 $\dfrac{46}{117} \times 100 = 39.3\%$

2

$ZnCl_2 + H_2$

136.4 2.0 $\dfrac{2}{138.4} \times 100 = 1.5\%$

3

$2Fe + 3CO_2$

$2(55.8)$ $3(44.0)$ $\dfrac{111.6}{243.6} \times 100 = 45.8\%$

4

$CaO + CO_2$

56.1 44.0 $\dfrac{56.1}{100.1} \times 100 = 56.0\%$

5

                 100%

6

$2H_2O + O_2$

$2(18)$ 32 $\dfrac{32}{68} \times 100 = 47.1\%$

7

a)   moles $NH_3 = \dfrac{340}{17} = 20$

    mass $N_2H_4 = 10 \times 32 = 320\,g$

b) $\% = \dfrac{280}{320} \times 100 = 87.5\%$

c) $N_2H_4 + NaCl + H_2O$

    32 58.5 18 $\dfrac{32}{108.5} \times 100 = 29.5\%$

d)   % yield: compares amount produced compared to amount that should be produced

    Atom economy: proportion of the mass of all the products that is the desired product

TASK 15 – Empirical & molecular formulas

1   a CH_3 b P_2O_3 c SO_2 d CH_2
     e CH_2O f C_2H_7N g B_3H_5 h $C_{12}H_{22}O_{11}$

2   a N_2H_4 b C_4H_{10} c C_5H_{10} d PH_3 e C_6H_6 f C_3H_6

3   a 3:2   b 1:2   c 5:1   d 2:5
     e 3:4   f 5:3   g 4:5   h 4:7

4   a $CaBr_2$ b $Na_2S_2O_3$ c C_2H_7N d CO_2 e NO_2

5 $FeCl_3$ 6 K_2SO_4 7 P_2O_3, P_4O_6 8 CH_2O, $C_2H_4O_2$

9 $C_5H_{10}O$, $C_5H_{10}O$ 10 x = 4, y = 2

1   a) CH_3 e) CH_2O
     b) P_2O_3 f) C_2H_7N
     c) SO_2 g) B_3H_5
     d) CH_2 h) $C_2H_{22}O_{11}$

2   a) $NH_2 \times \frac{32}{16} = N_2H_4$
     b) $C_2H_5 \times \frac{58}{29} = C_4H_{10}$
     c) $CH_2 \times \frac{70}{14} = C_5H_{10}$
     d) $PH_3 \times \frac{34}{34} = PH_3$
     e) $CH \times \frac{78}{13} = C_6H_6$
     f) $CH_2 \times \frac{42}{14} = C_3H_6$

3   a) 3:2   e) 3:4
     b) 1:2   f) 5:3
     c) 5:1   g) 4:5
     d) 2:5   h) 4:7

4   a) Ca 20/40.1 = 0.499   1
        Br 80/79.9 = 1.001   2 $CaBr_2$

     b) Na 29.1/23.0 = 1.265   2
        S   40.5/32.1 = 1.262   2
        O   30.4/16.0 = 1.900   3 $Na_2S_2O_3$

     c) C   53.3/12.0 = 4.442   2
        H   15.5/1.0 = 15.500   7
        N   31.1/14.0 = 2.221   1 C_2H_7N

d)   C $2.73/12.0 = 0.228$ 1

     O $7.27/16.0 = 0.454$ 2 CO_2

e)   N $15.2/14.0 = 1.09$ 1

     O $34.8/16.0 = 2.175$ 2 NO_2

5   Fe $3.53/55.8 = 0.0633$ 1

     Cl $6.71/35.5 = 0.189$ 3 $FeCl_3$

6   K $22.4/39.1 = 0.573$ 2

     S $9.2/32.1 = 0.287$ 1

     O $18.4/16.0 = 1.150$ 4 K_2SO_4

7   P $56.4/31.0 = 1.82$ 2   Emp = P_2O_3

     O $43.6/16.0 = 2.73$ 3

     Molec : $P_2O_3 \times \frac{220}{110} = P_4O_6$

8   C $40.0/12.0 = 3.33$ 1

     H $6.7/1.0 = 6.7$ 2

     O $53.5/16.0 = 3.34$ 1   Emp : CH_2O

     Molec : $CH_2O \times \frac{60}{30} = C_2H_4O_2$

9   C $1.10 \times \frac{12}{44} = 0.3 g$ $\therefore$ O = $0.08 g$

     H $0.45 \times \frac{2}{18} = 0.05 g$

     C $0.3/12.0 = 0.025$ 5

     H $0.05/1.0 = 0.05$ 10

     O $0.08/16.0 = 0.005$ 1 $C_5H_{10}O$

     Molec = $C_5H_{10}O \times \frac{86}{86} = C_5H_{10}O$

10

Cr	S	N
$\frac{15.5}{52.0}$	$\frac{38.15}{32.1}$	$\frac{29.2}{14.0}$
$\frac{0.298}{0.298}$	$\frac{1.19}{0.298}$	$\frac{2.09}{0.298}$
1	3.99	7.01
1	4	7

$NH_4 [Cr(SCN)_4(NH_3)_2]$ x = 4   y = 2

TASK 16 – Ideal gas equation

1 a 473 K   b 98000 Pa   c 50 x 10^{-6} m^3 d 223 K   e 100000 Pa   f 3.2 x 10^{-3} m^3
2 1.24 x 10^{-3} m^3 3 0.786   4 104000 Pa 5 155 K 6 71.0 7 0.00380 m^3
8 7.75 x 10^{-4} m^3 9 3.36 g   10 0.000538 m^3 11 4.53 m^3 12 64.1 13 483 K
14 126000 Pa

1   a)   473 K

    b)   98000 Pa

    c)   50 x 10^{-6} m^3

    d)   223 K

    e)   100 000 Pa

    f)   3.2 x 10^{-3} m^3

2   $V = \dfrac{nRT}{P}$ = $\dfrac{0.4 \times 8.31 \times 373}{1000000}$ = 1.24 x 10^{-3} m^3

3   $n = \dfrac{PV}{RT}$ = $\dfrac{101000 \times 19400 \times 10^{-6}}{8.31 \times 300}$ = 0.786

4   $P = \dfrac{nRT}{V}$ = $\dfrac{0.05 \times 8.31 \times 50}{200 \times 10^{-6}}$ = 104000 Pa

5   $T = \dfrac{PV}{nR}$ = $\dfrac{90000 \times 2 \times 10^{-3}}{0.14 \times 8.31}$ = 155 K

6   $n = \dfrac{PV}{RT}$ = $\dfrac{101000 \times 2 \times 10^{-3}}{8.31 \times 273}$ = 0.0890

    Mr = $\dfrac{6.39}{0.0890}$ = 71.0

7   moles CaC$_2$ = $\dfrac{10}{64.1}$ = 0.156

    moles C$_2$H$_2$ = 0.156

    $V = \dfrac{nRT}{P}$ = $\dfrac{0.156 \times 8.31 \times 293}{100,000}$ = 0.00380 m^3

8   moles Sr(NO$_3$)$_2$ = $\dfrac{1.0}{211.6}$ = 0.004726

    moles gaseous products = $\dfrac{5}{2}$ x 0.004726 = 0.0118

    $V = \dfrac{nRT}{P}$ = $\dfrac{0.0118 \times 8.31 \times 798}{101000}$ = 7.75 x 10^{-4} m^3

9

$$n = \frac{PV}{RT} = \frac{0.1 \times 10^6 \times 1 \times 10^{-3}}{8.31 \times 293} = 0.0411 \text{ mol}$$

mol $KClO_3$ = $\frac{2}{3} \times 0.0411 = 0.0274$

mass $KClO_3$ = $122.6 \times 0.0274 = 3.36 \text{ g}$

10

mol Na = $\frac{1}{23.0} = 0.04348$

mol H_2 = 0.02174

$$V = \frac{nRT}{P} = \frac{0.02174 \times 8.31 \times 298}{120000} = 0.000538 \text{ m}^3$$

11

mol C_3H_8 = $\frac{1000}{44.0} = 22.73$

mol CO_2 = 68.18

$$V = \frac{nRT}{P} = \frac{68.18 \times 8.31 \times 800}{100,000} = 4.53 \text{ m}^3$$

12

$$n = \frac{PV}{RT} = \frac{101000 \times 1 \times 10^{-3}}{8.31 \times 298} = 0.0408$$

$$Mr = \frac{2.615}{0.0408} = 64.1$$

13

$$n = \frac{PV}{RT} = \frac{8.7 \times 10^4 \times 2.75 \times 10^{-3}}{8.31 \times 290} = 0.0993$$

$$T = \frac{PV}{nR} = \frac{1.01 \times 10^5 \times 3.95 \times 10^{-3}}{8.31 \times 0.0993} = 483 K$$

14

$$n = \frac{PV}{RT} = \frac{101000 \times 3.25 \times 10^{-3}}{8.31 \times 298} = 0.1326$$

$$P = \frac{nRT}{V} = \frac{0.1326 \times 8.31 \times 373}{3.25 \times 10^{-3}} = 126000 \text{ Pa}$$

TASK 17 – Reacting gas volumes

1   a O_2 2 dm^3, CO_2 1 dm^3 b O_2 120 cm^3, CO_2 80 cm^3

      c O_2 1250 cm^3, CO_2 1000 cm^3 d O_2 5625 cm^3, CO_2 4500 cm^{3}q

2   20 cm^3 HBr left at end

3   300 cm^3 O_2, 100 cm^3 CO_2, total 400 cm^3 gas at end

4   4 dm^3 O_2, 4 dm^3 H_2O, 4 dm^3 SO_2, total 12 dm^3 gas

5   C_8H_{18}

5 $C_nH_{2n+2} + \frac{3n+1}{2}O_2 \rightarrow nCO_2 + (n+1)H_2O$

Ratio $C_nH_{2n+2} : O_2 = 0.5 : 6.25 = 1 : 12.5$

$\frac{3n+1}{2} = 12.5$ $3n + 1 = 25$ $3n = 24$ $n = 8$ C_8H_{18}

CHALLENGE 2

1   44.0   2 3.21 : 1, 130.5 g   3 NS   4 C_2H_4 5 515 ms^{-1} 6 C_3H_8

1

Assume 1 dm³:

✓ n = PV/RT

✓   = 1·01×10⁵ × 1×10⁻² / 8·31 × 323

✓   = 0·0377

✓ Mr = 1·655 / 0·0377 = 44·0

2

a 10 NaN₃ ⟶ 10 Na + 15 N₂

    ↓ 2 KNO₃

    K₂O + 5 Na₂O + N₂   ∴ gives 16 N₂

∴ ratio NaN₃ : KNO₃

    = 10 mol : 2 mol

    = 10(65) : 2(101.1)

    = 650 : 202.2 = 3.21 : 1
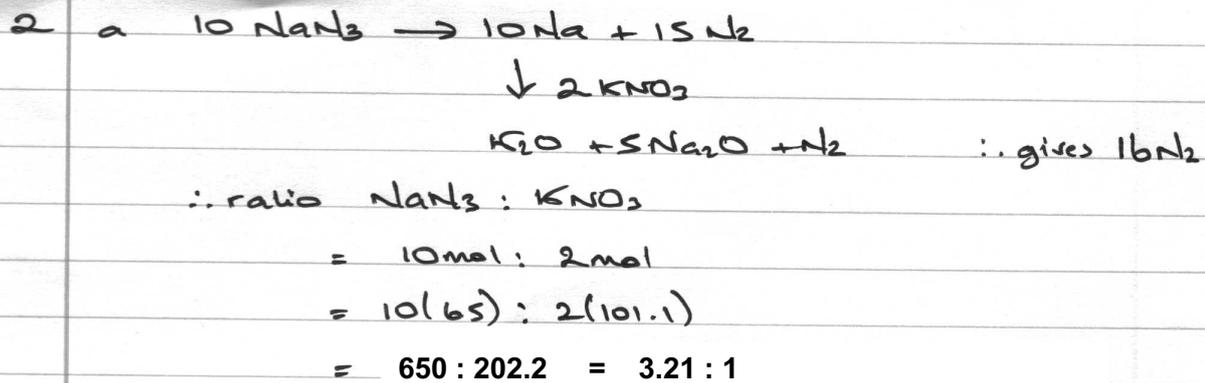
b mol N₂ = $\frac{PV}{RT}$ = $\frac{101000 \times 60 \times 10^{-3}}{8.31 \times 298}$ = 2.45 mol

    mass N₂ = 2.45 × 28.0 = 68.6 g

16(28.0) g = 448 g of N₂ from (650 + 202.2 =) 852.2 g of mixture

1 g of N₂ from $\frac{852.2}{448}$g = 1.90 g of mixture

68.6 g of N₂ from 1.90 x 68.6 = 130.5 g of mixture

3

✓ moles H₂S = $\frac{0.42}{22.4}$ = 0.01875

✓ moles S = $\frac{1}{32.0}$ = 0.03125

✓	S	NH₃	H₂S	NaSₑ
S	0.03125		0.01875	→ 0.0125
H		0.0375	0.0375	
N		0.0125		→ 0.0125

✓ ∴ <u>NS</u>

4 ✓

$$C_xH_y + (x+\tfrac{y}{4})O_2 \rightarrow x\,CO_2 + \tfrac{y}{2}H_2O$$

Start	15	60		
✓ End		15	30	
✓ Used	15	45		

✓ $\therefore x = 2$

✓ $y = 4$

✓ C_2H_4
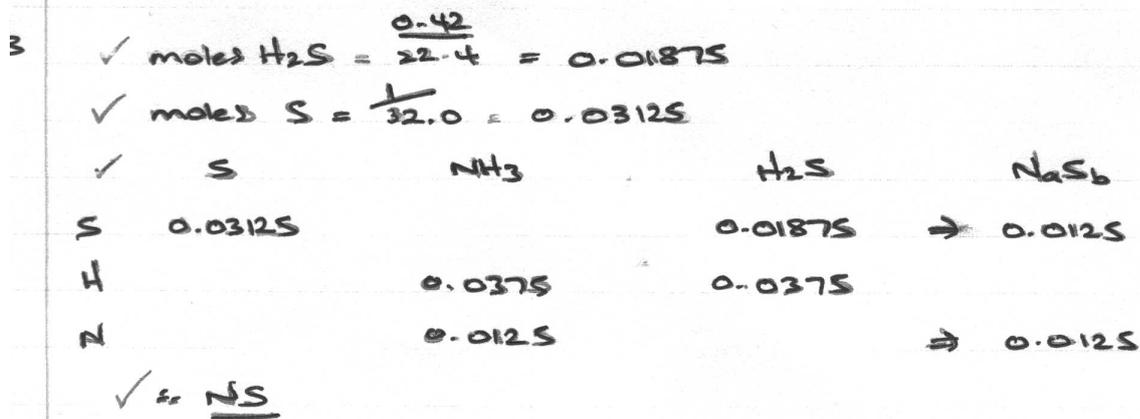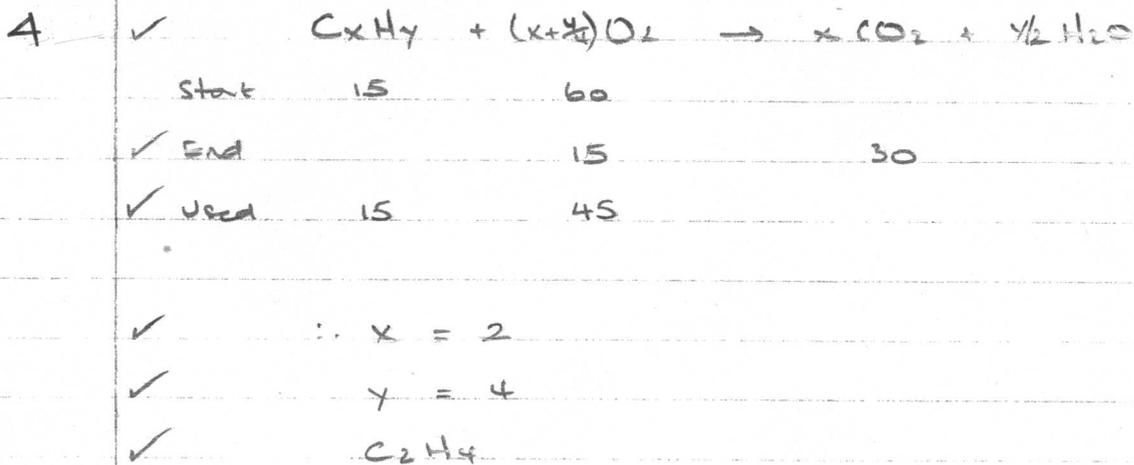
5

$$v^2 = \frac{3RT}{M} \qquad M = kg/mole \qquad N_2 = 0.028$$

$$v = \sqrt{\frac{3 \times 8.31 \times 298}{0.028}} = 515\ ms^{-1}$$

6

$$C_xH_y + x+\tfrac{y}{4}\,O_2 \rightarrow x\,CO_2 + \tfrac{y}{2}H_2O$$

Start	10			
End	-		30	

$\therefore x = 3$

$1 + x + \tfrac{y}{4} + xs \qquad\qquad x + xs + \tfrac{y}{2}$

$\Rightarrow vol\,O_2 = 50cm^3 \qquad\qquad \Rightarrow C_3H_8$
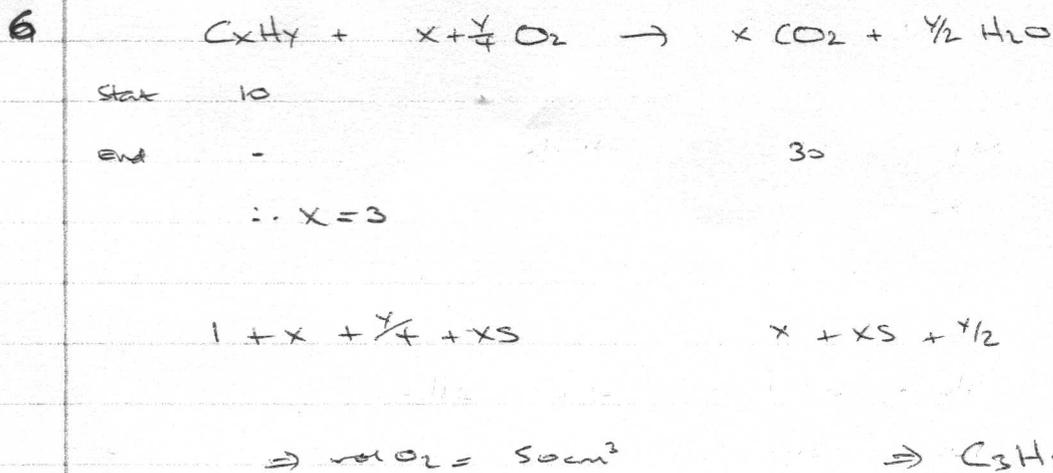
Calculations CHECK-UP

1   a $Zn(NO_3)_2$ b Pb c Cr_2O_3 d $(NH_4)_2SO_4$
    e P_4 f N_2 g $Ba(OH)_2$ h $Al_2(SO_4)_3$

2   H_2SO_4, KOH, 1:2; HCl, $KHCO_3$, 1:1; HNO_3, NH_3, 1:1; HCl, $ZnCO_3$, 2:1

3   a $H^+ + OH^- \rightarrow H_2O$ b $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$
    c $H^+ + NH_3 \rightarrow NH_4^+$ d $H^+ + HCO_3^- \rightarrow H_2O + CO_2$

4   a   average mass of an atom, relative to 1/12th mass of ^{12}C atom   b   it is the agreed standard
    c   mixture of other isotopes

5   a H_2, NH_3 = 3.33   b H_2, NH_3 = 3.33
    c N_2, NH_3 = 20.0   d H_2, NH_3 = 0.033

6   $3.10 \times 10^{-4}\,m^3$ 7 8.21×10^{-3}

8   a   volume of CO_2 = 57.1 cm^3, total = 128.5 cm^3 b   volume of CO_2 = 200 cm^3, total = 350 cm^3
    c   volume of CO_2 = 229 cm^3, total = 314 cm^3

9   $2.00 \times 10^{-3}\,m^3$ 10   1.64 m^3

11   a   40, 60   b   40.0, 20.0   c   5.84, 8.76

12   193.5 g   13   9.39 g

14   a   1250 g   b   i 96%   ii reversible, product lost on isolation, other reactions   iii 100%

15   a   529 g   b   94.5%   c   52.9%   16   7

17   a   0.05, 0.05, $1.22 \times 10^{-3}\,m^3$, 4.07 g   b   1.30 g, 2.77 g

1) Give the formula of each of the following substances.

a) zinc nitrate ✓ $Zn(NO_3)_2$ e) phosphorus ✓ P_4

b) lead ✓ Pb f) nitrogen ✓ N_2

c) chromium (III) oxide ✓ Cr_2O_3 g) barium hydroxide ✓ $Ba(OH)_2$

d) ammonium sulphate ✓ $(NH_4)_2SO_4$ h) aluminium sulphate ✓ $Al_2(SO_4)_3$ (8)

2) Use your knowledge of ionic equations to give the molar ratio in which the following acids react with bases. Complete the table to show your answers. (4)

Acid	Formula of acid	Base	Formula of base	Molar ratio of acid:base
sulphuric acid	H_2SO_4	potassium hydroxide	KOH	1 : 2 ✓
hydrochloric acid	HCl	potassium hydrogencarbonate	$KHCO_3$	1 : 1 ✓
nitric acid	HNO_3	ammonia	NH_3	1 : 1
hydrochloric acid	HCl	zinc carbonate	$ZnCO_3$	2 : 1

3) Write ionic equations for each of the following reactions. ✓ eq ✓ state symbols

a) reaction of sulphuric acid (aq) and sodium hydroxide (aq)

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$ (2)

b) precipitation of barium carbonate by mixing solutions of barium hydroxide and sodium carbonate

$$Ba^{2+}(aq) + CO_3^{2-}(aq) \rightarrow BaCO_3(s)$$ (2)

c) reaction of nitric acid (aq) and ammonia (aq)

$$H^+(aq) + NH_3(aq) \rightarrow NH_4^+(aq)$$ (2)

d) reaction of sulphuric acid (aq) and potassium hydrogencarbonate (aq)

$$H^+(aq) + HCO_3^-(aq) \rightarrow H_2O(l) + CO_2(g)$$ (2)

4) a) Define the term relative atomic mass. ✓ average mass of atom ✓ relative to 1/12th mass ^{12}C atom (2)

b) Explain why ^{12}C is referred to in the definition. ✓ agreed standard (1)

c) Explain why carbon has a relative atomic mass of 12.011 and not exactly 12.000. ✓ mixture of / other isotopes (1)

5) In each case work out the limiting reagent and moles of ammonia formed (assuming complete reaction).

$$N_2 + 3 H_2 \rightarrow 2 NH_3$$

a) 5 moles of N_2 + 5 moles of H_2 limiting reagent = ...H_2...   moles of NH_3 formed = ..3.33... (1) ✓

b) 2 moles of N_2 + 5 moles of H_2 limiting reagent = ...H_2...   moles of NH_3 formed = ..3.33.... (1) ✓

c) 10 moles of N_2 + 50 moles of H_2 limiting reagent = ...N_2...   moles of NH_3 formed = ..20...... (1) ✓

d) 0.2 moles of N_2 + 0.05 moles of H_2 limiting reagent = ...H_2...   moles of NH_3 formed = ..0.033.. (1) ✓

6) Calculate the volume of 0.200 moles of carbon dioxide at 100°C and 2 MPa pressure.

$$PV = nRT \qquad V = \frac{nRT}{P} ✓ = \frac{0.200 \times 8.31 \times 373}{2\,000\,000} ✓$$

$$= 3.10 \times 10^{-4} \text{ m}^3 ✓$$

(3)

7) Calculate the number of moles of argon in 200 cm³ at 100 kPa at 20°C.

$$PV = nRT \qquad n = \frac{PV}{RT} ✓ = \frac{100\,000 \times 200 \times 10^{-6}}{8.31 \times 293} ✓$$

$$= 8.21 \times 10^{-3} ✓$$

(3)

8) The equation is for the combustion of ethane in oxygen. $C_2H_6(g) + 3\frac{1}{2} O_2(g) \rightarrow 2 CO_2(g) + 3 H_2O(l)$

What volume of carbon dioxide is formed and what is the total volume of gases at the end in each of the following reactions.

a) 100 cm³ of ethane + 100 cm³ of oxygen

volume of CO_2 formed = ...57.1 cm³... ✓   Total volume of gases at end = ...128.5 cm³ ✓ (2)

b) 100 cm³ of ethane + 500 cm³ of oxygen

volume of CO_2 formed = ...200 cm³... ✓   Total volume of gases at end = ...350 cm³ ✓ (2)

c) 200 cm³ of ethane + 400 cm³ of oxygen

volume of CO_2 formed = ...228.6 cm³ ✓   Total volume of gases at end = ...314.3 cm³ ✓ (2)

9) What volume of hydrogen is formed at 20°C and 100000 Pa pressure when 2 g of magnesium is reacted with excess sulphuric acid?

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$$

✓ mol. Mg = $^2/_{24.3}$ = 0.0823

✓ mol. H_2 = 0.0823

$$V = \frac{nRT}{P} = \frac{0.0823 \times 8.31 \times 293}{100\,000} ✓ = 2.00 \times 10^{-3} \text{ m}^3 ✓$$

(4)

10) What volume of carbon monoxide is formed at 1200°C and 0.14 MPa pressure when 1 kg of iron oxide is reduced by carbon?

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

$\therefore$ mol $Fe_2O_3 = \dfrac{1000}{159.6} = 6.27$ ✓

mol $CO = 18.80$ ✓

$V = \dfrac{nRT}{P} = \dfrac{18.80 \times 8.31 \times 1473}{0.14 \times 10^6}$ ✓ $= 1.64\ m^3$ ✓

(4)

11) a) In 20 moles of Al_2O_3,

   i) how many moles of Al^{3+} ions? .... 40 ✓

   ii) how many moles of O^{2-} ions? .... 60 ✓   (2)

   b) In 360 g of water $\dfrac{360}{18.0} = 20\ moles\ H_2O$

   i) how many moles of H atoms? .... 40 ✓

   ii) how many moles of O atoms? .... 20 ✓   (2)

   c) In 1 kg of aluminium sulphate $Al_2(SO_4)_3$ $\dfrac{1000}{342.3} = 2.92$

   i) how many moles of aluminium ions? .... 5.84 ✓

   ii) how many moles of sulphate ions? .... 8.76 ✓   (2)

12) What mass of Fe_3O_4 is produced when 140 g of iron reacts with excess steam?

$$3Fe(s) + 4H_2O(g) \rightarrow Fe_3O_4(s) + 4H_2(g)$$

✓ mol $Fe = \dfrac{140}{55.8} = 2.51$

✓ mol $Fe_3O_4 = 0.836$

✓ mass $Fe_3O_4 = 231.4 \times 0.836 = 193.5\ g$ (3)

13) What mass of potassium oxide is formed when 7.8 g of potassium is burned in oxygen?

$$4K + O_2 \rightarrow 2K_2O$$

✓ mol $K = \dfrac{7.8}{39.1} = 0.199$

✓ mol $K_2O = 0.0997$

✓ mass $K_2O = 94.2 \times 0.0997 = 9.39\ g$ (3)

14 a) Sulfur trioxide is made from sulfur dioxide by the following reaction. Calculate the maximum amount of sulfur trioxide that can be made from 1 kg of sulfur dioxide.

$$2 SO_2 + O_2 \leftrightharpoons 2 SO_3$$
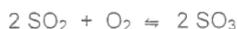
✓ mol SO_2 = $\dfrac{1000}{64.1}$ = 15.60

✓ mol SO_3 = 15.60

✓ mass SO_3 = 80.1 × 15.60 = 1250 g   (3)

b) In an experiment, only 1200 g of sulfur trioxide was produced.

   i) Calculate the percentage yield. $\dfrac{1200}{1250}$ × 100 = 96% ✓   (1)

   ii) Give three reasons why the yield is less than 100%.

   ✓ • may be reversible

   ✓ • other reactions may take place

   ✓ • some product may be lost on separation   (1)

c) Calculate the atom economy for this process..... ✓ 100%   (1)

15 a) Aluminium is made from aluminium oxide by electrolysis. Calculate the mass of aluminium that can be made from 1 kg of aluminium oxide.

$$2 Al_2O_3 \rightarrow 4 Al + 3 O_2$$

✓ mol Al_2O_3 = $\dfrac{1000}{102}$ = 9.80

✓ mol Al = 19.61

✓ mass Al = 27.0 × 19.61 = 529 g   (3)

b) Calculate the percentage yield if 500 g of aluminium is produced.

$\dfrac{500}{529}$ × 100 = 94.5% ✓   (1)

c) Calculate the atom economy for this process.

$\begin{array}{cc} 4Al + 3O_2 \\ 4(27) + 3(32) \\ 108 \quad\quad 96 \end{array}$ $\dfrac{108}{108+96}$ × 100 = 52.9% ✓   (1)

16 When 12.3 g of $MgSO_4.nH_2O$ is heated gently until no further change in mass occurs, to remove the water of crystallisation, 6.0 g of anhydrous magnesium sulfate ($MgSO_4$) remained. Work out the relative formula mass (M_r) of the $MgSO_4.nH_2O$, and so the value of n.

$$MgSO_4.nH_2O \rightarrow MgSO_4 + n H_2O$$

✓ mol $MgSO_4$ = 6.0/120.4 = 0.0498

✓ mol $MgSO_4.nH_2O$ = 0.0498

✓ M_r $MgSO_4.nH_2O$ = 12.3/0.0498 = 246.8

$\underset{120.4}{MgSO_4}.\underset{246.8}{nH_2O}$ $n = \dfrac{126.4}{18.0}$ = 7.02 $n = 7$ ✓

$\begin{array}{r} 246.8 \\ -120.4 \\ \hline 126.4 \end{array}$ (4)

17) Since 1850, most books and documents have been printed on acidic paper which, over time, becomes brittle and disintegrates. By treating books with diethyl zinc vapour, the acids in the book are neutralised. Diethyl zinc vapour penetrates the closed book and reacts with the small amount of water in the paper to form zinc oxide. The zinc oxide neutralises the acids and protects the book from acids that may be formed later. There is virtually no difference between treated and untreated books.

The reaction between diethyl zinc and water is represented by the equation:

$$Zn(C_2H_5)_2(g) + H_2O(l) \rightarrow ZnO(s) + 2 C_2H_6(g)$$
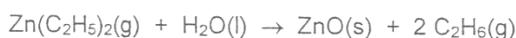
The total moisture content of a book which was treated was found to be 0.9 g of water.

a) i) How many moles of water were present in the book? ....

.... $mol\ H_2O = \dfrac{0.9}{18.0} = 0.05$ ✓ .... (1)

ii) Using the equation, how many moles of diethyl zinc would react with this amount of water?

.... 0.05 ✓ .... (1)

iii) What is the volume at room temperature and pressure of this amount of diethyl zinc vapour? ~~(The volume of one mole of gas at room temperature and pressure is 24 dm³)~~

... $V = \dfrac{nRT}{P} = \dfrac{0.05 \times 8.31 \times 293}{100,000} = 1.22 \times 10^{-3}\ m^3$ ✓ .... (1)

iv) What mass of zinc oxide would be formed in the book? ... $Mr = 81.4$ ✓ ....

.... $81.4 \times 0.05 = 4.07\ g$ ✓ .... (2)

b) The acid content of the book was found to be 0.032 moles of $H^+_{(aq)}$. The equation for the reaction between zinc oxide and acid is:

$$ZnO(s) + 2 H^+(aq) \rightarrow Zn^{2+}(aq) + H_2O(l)$$

i) Calculate the mass of zinc oxide required to neutralise the acid in the book.

✓ $mol = 0.016$ .... ∴ $mass = 81.4 \times 0.016 = 1.30\ g$ ✓ .... (2)

ii) Hence calculate the mass of excess zinc oxide which remains in the book.

.. ✓ $4.07 - 1.30$ ....

.. ✓ $= 2.77\ g$ .... (2)

TASK 18 – Solution calculations

1   a   0.1   b   250   c   0.0025

2   a   0.2 mol dm^{-3}, 7.3 g dm^{-3} b   2.5 mol dm^{-3}, 245.3 g dm^{-3} c   0.0525 mol dm^{-3}, 2.10 g dm^{-3}

3   a   0.05 dm^3 b   0.001 dm^3

4   0.0269 mol dm^{-3}, 4.61 g dm^{-3} 5   0.0752 mol dm^{-3}, 3.01 g dm^{-3} 6   0.00750 dm^3

7   0.05000 mol dm^{-3}, 7.10 g dm^{-3} 8   1.13 g   9   79.9 dm^3

10   87.8   11   2   12 A_r = 39.1, K

1   a)   mol = 2 × 0.05 = 0.1

    b)   mol = 5 × 50 = 250

    c)   mol = 0.25 × $\frac{10}{1000}$ = 0.0025

2   a)   conc = $\frac{0.4}{2.0}$ = 0.2 mol/dm^3 Mr = 36.5   ⇒   7.3 g/dm^3

    b)   conc = $\frac{12.5}{5.0}$ = 2.5 mol/dm^3 Mr = 98.1   ⇒   245.3 g/dm^3

    c)   mol NaOH = $\frac{1.05}{40.0}$ = 0.02625 mol   conc = $\frac{0.02625}{500/1000}$ = 0.0525 mol dm^{-3} ⇒   2.10 g dm^{-3}

3   a)   vol = $\frac{0.005}{0.1}$ = 0.05 dm^3

    b)   vol = $\frac{1 \times 10^{-5}}{0.01}$ = 0.001 dm^3

4   a)   mol H$_2$SO$_4$ = 0.02 × $\frac{25}{1000}$ = 0.0005

       mol Ba(OH)$_2$ = 0.0005

       conc Ba(OH)$_2$ = $\frac{0.0005}{18.6/1000}$ = 0.0269 mol/dm^3

    b)   Mr Ba(OH)$_2$ = 171.3

       conc = 4.61 g/dm^3

5   a)   mol H$_2$SO$_4$ = 0.05 × $\frac{18.8}{1000}$ = 0.00094

       mol NaOH = 0.00188

       conc NaOH = $\frac{0.00188}{25/1000}$ = 0.0752 mol dm^{-3}

    b)   Mr NaOH = 40.0

       conc = 3.01 g/dm^3

6   mol HNO$_3$ = 0.015 × $\frac{25}{1000}$ = 0.000375

    mol KOH = 0.000375

    vol KOH = $\frac{0.000375}{0.05}$ = **0.00750 dm^3**

7   a)   mol NaOH $= 0.10 \times \frac{37.5}{1000} = 0.00375$

mol $H_3AsO_4 = 0.00125$

conc $H_3AsO_4 = \frac{0.00125}{\frac{25}{1000}} = 0.05$ mol dm⁻³

b) $M_r = \frac{125.9}{141.9}$

conc $= \frac{18.9}{7.10}$ g dm⁻³

8   mol HCl $= 0.1 \times \frac{28.2}{1000} = 0.00282$

mol NaOH in 25 $= 0.00282$

mol NaOH in 250 $= 0.0282$

mass NaOH $= 40.0 \times 0.0282 = 1.13$ g

9   mol $CaCO_3 = \frac{20000}{100.1} = 199.8$

mol HCl $= 399.6$

vol HCl $= \frac{399.6}{5.0} = 79.9$ dm³

10   mol NaOH $= 0.075 \times \frac{46.5}{1000} = 0.00442$

mol acid in 25 $= 0.00442$

mol acid in 250 $= 0.0442$

$M_r = \frac{3.88}{0.0442} = 87.8$

11   mol NaOH $= 0.16 \times \frac{15.6}{1000} = 0.002496$

mol $H_2C_2O_4 . nH_2O$ in 25 $= 0.001248$

mol $H_2C_2O_4 . nH_2O$ in 250 $= 0.01248$

$M_r = \frac{1.575}{0.01248} = 126.2$

$n = \frac{126.2 - 90}{18} = \frac{36.2}{18} = 2$

12   mol HCl $= 0.100 \times \frac{27.0}{1000} = 0.0027$

mol M_2CO_3 in 25 $= 0.00135$

mol M_2CO_3 in 250 $= 0.00135 \ 0.0054$

$M_r = \frac{7.46}{0.054} = 138.1$

$M_L \Rightarrow 138.1 - 60 = 78.1$

$M \Rightarrow 39.1 \qquad \Rightarrow K.$

TASK 19 – Back titration calculations

1   87.7%   2   90.8%   3   0.0500 mol, 4.22 g
4   0.606 g   5   4.68 g

1

$NaOH + HCl \rightarrow$ $CaCO_3 + 2HCl \rightarrow$

mol NaOH to react with XS acid $= 0.100 \times \frac{24.8}{1000} = 0.00248$

mol XS HCl $= 0.00248$

mol HCl originally $= 0.200 \times \frac{100}{1000} = 0.02$

∴ mol HCl reacting with $CaCO_3 = 0.01752$

mol $CaCO_3 = 0.00876$

mass $CaCO_3 = 100.1 \times 0.00876 = 0.877$ g

% purity of limestone $= \frac{0.877}{1.00} \times 100 = \underline{87.7\%}$

2

mol NaOH for XS HCl $= 0.228 \times \frac{10.9}{1000} = 0.002485$

mol XS HCl $= 0.002485$

mol HCl @ start $= 0.2 \times \frac{100}{1000} = 0.02$

∴ mol HCl reacting $= 0.0175$

∴ mol $Ba(OH)_2 = 0.00876$ $Ba(OH)_2 + 2HCl$

∴ mass $Ba(OH)_2 = 171.3 \times 0.00876 = 1.50$ g

% $= \frac{1.50}{1.6524} \times 100 = 90.8\%$

3

mol NaOH in titration $= 0.03$

mol $Fe SO_4$ in each titration $= 0.015$

∴ mol H_2SO_4 left over in stock solution $= 0.15$

mol H_2SO_4 @ start $= 0.2$

∴ mol H_2SO_4 reacting with $MgCO_3 = 0.2 - 0.15 = 0.05$

∴ mol $MgCO_3 = 0.05$

∴ mass $MgCO_3 = 84.3 \times 0.05 = 4.22g$

4

NaOH + HCl ⟶ $CaCO_3 + 2HCl$ ⟶

mol NaOH reacting with xs HCl $= 0.50 \times \frac{25.8}{1000} = 0.0129$

∴ mol xs HCl $= 0.0129$

mol HCl originally added to $CaCO_3 = 1.00 \times \frac{25}{1000} = 0.025$

∴ mol HCl that reacted with $CaCO_3 = 0.025 - 0.0129 = 0.0121$

∴ mol $CaCO_3 = 0.00605$

mass $CaCO_3 = 100.1 \times 0.00605 = \underline{\underline{0.606 \text{ g}}}$

5   moles HCl to neutralise leftover NaOH $= \frac{50}{1000} \times 0.250 = 0.0125$

moles NaOH that reacts with HCl $= 0.0125$

original moles of NaOH added to $NH_4Cl = \frac{100}{1000} \times 1.00 = 0.100$

moles of NaOH that reacted with $NH_4Cl = 0.100 - 0.0125 = 0.0875$

mass of $NH_4Cl = 0.0875 \times 53.5 = 4.68$ g

1   9.67%   2   **A** Si_2OCl_6

1

$$(NH_4)_2SO_4 + 2NaOH \longrightarrow 2NH_3 + Na_2SO_4 + 2H_2O$$

$$NaOH + HCl \rightarrow NaCl + H_2O$$

✓ mol HCl = conc × vol = $0.100 \times \frac{28.7}{1000}$ = 0.00287

✓ mol left over NaOH = 0.00287

✓ original NaOH = conc × vol = $0.2 \times \frac{25}{1000}$ = 0.00500

✓ ∴ NaOH that reacted with fertiliser = 0.005 − 0.00287 = 0.00213

✓ ∴ mol $(NH_4)_2SO_4$ = 0.00213/2 = 0.001065

✓ ∴ mass $(NH_4)_2SO_4$ = Mr × moles = 132.1 × 0.001065 = 0.1407 g

⑦ ✓ ∴ % $(NH_4)_2SO_4$ = $\frac{0.1407}{1.455}$ × 100 = **9.67%**

2

mol $AgNO_3$ = $0.05 \times \frac{42.10}{1000}$ = 0.002105

$$Ag^+ + Cl^- \rightarrow AgCl$$

∴ mol Cl^- = 0.002105

∴ mass Cl in sample = 0.002105 × 35.5 = 0.0747g

Ⓐ Si_2OCl_6 % Cl = $\frac{6(35.5)}{285.2}$ × 100 = 74.7%

Ⓑ $Si_3O_2Cl_8$ % Cl = $\frac{8(35.5)}{400.3}$ × 100 = 70.9%

∴ Compound is Ⓐ Si_2OCl_6

Calculation Allsorts

1 $C_5H_{11}NO$ 2 $C_{11}H_{14}O_2$, $C_{11}H_{14}O_2$ 3 526 g 4 2.71 g 5 5.00 dm^3

6 0.0241 mol dm^{-3} 7 234.9 8 3.21% 9 55.0%

10 $10\,Al + 6\,NH_4ClO_4 \rightarrow 3\,N_2 + 9\,H_2O + 6\,HCl + 5\,Al_2O_3$

---

①

C	59.4/12.0	4.95	10.99	5
H	10.9/1.0	10.9	10.99	11
N	13.9/14.0	0.99	10.99	1
O	15.8/16.0	0.99	10.99	1

$C_5H_{11}NO$

②

C	74.2/12.0	6.18 /1.12	5.5	11
H	7.9/1.0	7.9 /1.12	7.0	14
O	17.9/16.0	1.12 /1.12	1.0	2

empirical = $C_{11}H_{14}O_2$

molecular = $C_{11}H_{14}O_2$

③

mol Fe_2O_3 = $\frac{1000}{159.6}$ = 6.27 mol

mol CO = 6.27 × 3 = 18.80 mol

mass CO = 18.80 × 28.0 = 526 g

526 g

④

mol Fe_2O_3 = $\frac{8.00}{159.6}$ = 0.0501 mol

mol Al = 0.0501 × 2 = 0.1003 mol

mass Al = 0.1003 × 27.0 = 2.71 g

2.71 g

⑤

mol $CaCO_3$ = $\frac{25.0}{100.1}$ = 0.250 mol

mol HCl = 2 × 0.250 = 0.500 mol

vol HCl = 0.500/0.100 = 5.00 dm^3

5.00 dm^3

⑥

$H_2SO_4 + 2\,NaOH \longrightarrow$

mol NaOH = 0.0400 × 25.0/1000 = 0.00100 mol

mol H_2SO_4 = 0.00100 ÷ 2 = 0.000500 mol

conc H_2SO_4 = 0.000500/20.75/1000 = 0.0241 mol dm^{-3}

0.0241 mol dm^{-3}

⑦

HA + NaOH $\longrightarrow$

mol NaOH = 0.250 × 23.5/1000 = 0.005875

mol HA in 25 cm^3 = 0.005875

mol HA in 250 cm^3 = 0.05875

M_r HA = 13.8/0.05875 = 234.9

234.9

(8)   NaOH + HCl $\longrightarrow$

mol NaOH = $0.200 \times \frac{36.8}{1000}$ = 0.00736

∴ 1/10th of XS HCl = 0.00736

∴ XS HCl = 0.0736

Mg + 2HCl $\longrightarrow$

original HCl = $1.00 \times \frac{100}{1000}$ = 0.100

mol HCl reacting with HCl = 0.100 − 0.0736 = 0.0264

mol Mg = 0.0264 ÷ 2 = 0.0132

mass Mg = 0.0132 × 24.3 = 0.321 g

∴ % Mg = $\frac{0.321}{10.0} \times 100$ = 3.21%   3.21%

(9)   NaOH + HCl $\longrightarrow$

mol NaOH = $0.200 \times \frac{34.1}{1000}$ = 0.00682

∴ 1/10th of XS HCl = 0.00682

∴ XS HCl = 0.0682

CaCO₃ + 2HCl $\longrightarrow$

original HCl = $2.0 \times \frac{100}{1000}$ = 0.200

mol HCl reacting with CaCO₃ = 0.200 − 0.0682 = 0.1318

mol CaCO₃ = 0.1318 ÷ 2 = 0.0659

mass CaCO₃ = 100.1 × 0.0659 = 6.60 g

∴ % CaCO₃ = $\frac{6.60}{12.0} \times 100$ = 55.0%   55.0%

(10)   a) $10 Al + 6 NH_4ClO_4 \longrightarrow 3 N_2 + 9 H_2O + 6 HCl + 5 Al_2O_3$

b)   mol Al = $\frac{160 \times 10^6}{27.0}$ = 5.926×10^6

mol HCl = 3.56×10^6

mass HCl = 1.30×10^8 g