



1. B
2. B
3. D
4. C
5. A
6. A
7. B
8. C
9. B
10. D
11. D
12. B
13. C
14. D
15. D
16. A
17. C
18. C
19. B
20. A
21. D
22. C
23. C
24. C
25. B
26. B
27. C
28. A
29. A
30. D



- 31. A
- 32. C
- 33. A
- 34. C
- 35. C
- 36. C
- 37. C
- 38. B
- 39. D
- 40. C
- 41. B
- 42. B
- 43. D
- 44. C
- 45. A
- 46. B
- 47. D
- 48. A
- 49. B
- 50. A
- 51. C
- 52. C
- 53. C
- 54. C
- 55. D
- 56. B
- 57. C
- 58. C



59. C

60. Al  $\frac{20.3}{26.98}$  Cl  $\frac{79.70}{35.45}$  or similar working (*no penalty for use of 27 or 35.5*);

empirical formula  $\text{AlCl}_3$ ;

molecular formula:  $n = \frac{267}{133.5} = 2$ ;

$\text{Al}_2\text{Cl}_6$ ;

*Full credit can be obtained if the calculations are carried out by another valid method. Two correct formulas but no valid method scores [2 max].*

[4]

61. moles of Na =  $\frac{1.15}{23} = 0.05$ ;

moles of NaOH = 0.05;

*Accept "same as moles of Na"*

concentration =  $\left(\frac{0.05}{0.25}\right) = 0.20 \text{ (mol dm}^{-3}\text{)}$

3

*Allow ECF from moles of NaOH*

[3]

62. (i) bubbling/effervescence/dissolving of  $\text{CaCO}_3$ /gas given off  
(*do not accept  $\text{CO}_2$  produced*);  
more vigorous reaction with HCl/OWTTE;

2

(ii)  $2\text{HCl(aq)} + \text{CaCO}_3\text{(s)} \rightarrow \text{CaCl}_2\text{(aq)} + \text{CO}_2\text{(g)} + \text{H}_2\text{O(l)}$ ;

2

*[1] for correct formulas, [1] for balanced, state symbols not*

(iii) amount of  $\text{CaCO}_3 = \frac{1.25}{100.09}$  (*no penalty for use of 100*);

amount of HCl =  $2 \times 0.0125 = 0.0250 \text{ mol}$  (*allow ECF*);

volume of HCl =  $0.0167 \text{ dm}^3 / 16.7 \text{ cm}^3$  (*allow ECF*);

3

(iv) 1:1 ratio of  $\text{CaCO}_3$  to  $\text{CO}_2$  /use 0.0125 moles  $\text{CO}_2$  (*allow ECF*);

$(0.0125 \times 22.4) = 0.28 \text{ dm}^3 / 280 \text{ cm}^3 / 2.8 \times 10^{-4} \text{ m}^3$  (*allow ECF*);

1

*Accept calculation using  $pV=nRT$ .*

[9]

63. (a) % of oxygen = 36.4;

$\text{C} = \frac{54.5}{12.01}, \text{H} = \frac{9.1}{1.01}, \text{O} = \frac{36.4}{16.00}$ ;

*Do not penalize if 12, 1 and 16 are used.*

$\text{C}_2\text{H}_4\text{O}$ ;

3



If atomic numbers or incorrect  $A_r$  values used, only first mark can be scored.

Award [3] for correct formula without working.

(b)  $pV = nRT/pV = \frac{mRT}{M_r}$  /correct rearrangement;

$$M_r = \frac{0.230 \times 8.31 \times 368}{102 \times 10^3 \times 0.0785 \times 10^{-3}};$$

Award [1] for 368 even if incorrect expression given.

$$M_r = 87.8;$$

3

Accept answer in range 87.8 to 88.

Do not allow ECF.

Award [3] for correct final answer



1

Answer does not need to show working to receive the mark.

Do not allow ECF.

[7]

64. (i) C N H

$$\frac{62.0}{12.01} / 5.16 \quad \frac{24.1}{14.01} / 1.72 \quad \frac{13.9}{1.01} / 13.8$$

Award [2] for above.

No penalty for use of whole number atomic masses.

If atomic numbers used then only mark for % of H can be awarded.

If H % and calculation missing, award [1], and last mark cannot be scored.

If H % calculation incorrect apply ECF.



3

Correct empirical formula scores [3].

(ii) the average mass of a molecule;

compared to 1/12 of (the mass of) one atom of  $^{12}C$ /compared to C-12 taken as 12;

**OR**

$$\frac{\text{average mass of a molecule}}{\text{mass of } 1/12 \text{ of one atom of } ^{12}C}$$

2

Award [2] for the equation above.



1



[6]

65.	(i)	C	N	H
		$\frac{62.0}{12.01}/5.16$	$\frac{24.1}{14.01}/1.72$	$\frac{13.9}{1.01}/13.8$

*Award [2] for above.*

*No penalty for use of whole number atomic masses.*

*If atomic numbers used then only mark for % of H can be awarded.*

*If H % and calculation missing, award [1], and last mark cannot be scored.*

*If H % calculation incorrect apply ECF.*

$C_3NH_8$ ; 3  
*Correct empirical formula scores [3].*

- (ii) the average mass of a molecule;  
compared to 1/12 of (the mass of) one atom of  $^{12}C$ /compared to C-12 taken as 12;

**OR**

$$\frac{\text{average mass of a molecule}}{\text{mass of } 1/12 \text{ of one atom of } ^{12}C}$$
 2  
*Award [2] for the equation above.*

(iii)  $C_6N_2H_{16}$ ; 1

[6]

66. 60.0 dm<sup>3</sup> CO<sub>2</sub>;  
80.0 dm<sup>3</sup> H<sub>2</sub>O;  
20.0 dm<sup>3</sup> O<sub>2</sub>; 3  
*Apply -1(U).*

[3]

67. overall there will be no change to the pressure;  
double absolute temperature and the pressure doubles;  
double volume and the pressure halves;  
*Apply ECF if points 2 and 3 are incorrect.*

**OR**

Use  $PV = nRT$ , Since  $n$  and  $R$  are constant;  
 $V$  and  $T$  are both doubled;  
 $P$  will remain unchanged;

**OR**

OWTTE for mathematical interpretation



e.g.  $T \propto P$ , therefore  $2P$ ;  
 $V \propto 1/P$ , therefore  $\frac{1}{2}P$ ;  
No change to  $P$ ,  $\frac{1}{2}P \times 2P = P$ ;

3

68. (i)  $n(\text{C}) (= n(\text{CO}_2) = 2.68 \text{ g} \div 44.01 \text{ g mol}^{-1}) = 0.0609 \text{ mol}$ ;  
 $n(\text{H}) (= 2 \times n(\text{H}_2\text{O}) = 0.657 \text{ g} \div 18.02 \text{ g mol}^{-1}) = 0.0729 \text{ mol}$ ;  
 $m(\text{C}) = 0.0609 \text{ mol} \times 12.01 \text{ g mol}^{-1} = 0.731 \text{ g}$   
**and**  $m(\text{H}) = 0.0729 \text{ mol} \times 1.01 \text{ g mol}^{-1} = 0.0736 \text{ g}$ ;  
 $m(\text{O}) = (1.00 - 0.731 - 0.0736) \text{ g} = 0.195 \text{ g}$ ;

$n(\text{C})$	$n(\text{H})$	$n(\text{O})$
0.0609	0.0730	<u>0.195</u>
		16.00
0.0609	0.0730	0.0122
<u>0.0609</u>	<u>0.0730</u>	<u>0.0122</u>
0.0122	0.0122	0.0122
4.99	5.98	1.00;

empirical formula:  $\text{C}_5\text{H}_6\text{O}$ ;

*For  $\text{C}_5\text{H}_6$  award [4 max].*

*Steps used to arrive at the correct amounts (in moles) are required for full marks.*

6

- (ii)  $M(\text{crocetin}) = 98.5 \text{ g} \div 0.300 \text{ mol} = 328 \text{ (g mol}^{-1}\text{)}$ ;

$$\left(\frac{328}{82.11} = 4\right)$$

molecular formula:  $\text{C}_{20}\text{H}_{24}\text{O}_4$ ;

*ECF from (i).*

2

[8]

69. (i)  $\text{NH}_3(\text{aq}) + \text{HCl}(\text{aq}) \rightarrow \text{NH}_4\text{Cl}(\text{aq}) \square$ ;

*States not required for mark*

1

- (ii)  $n(\text{HCl}) = cV = 0.100 \text{ mol dm}^{-3} \times 0.0250 \text{ dm}^3 = 0.00250 \text{ mol}$ ;  
 $n(\text{NH}_3) = n(\text{HCl}) = 0.00250 \text{ mol}$ ;

*ECF*

2

- (iii)  $(M(\text{NH}_3) = 14.01 + 3(1.01) =) 17.04/17.0 \text{ (g mol}^{-1}\text{)}$ ;  
 $m(\text{NH}_3) = 0.00250 \text{ mol} \times 17.04 \text{ g mol}^{-1} = 0.0426 \text{ g}/0.0425 \text{ g}$ ;

*ECF*

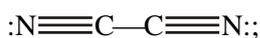
2

[5]

70. empirical formula = CN;

*Working must be shown to get point.*

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



3

[3]

71. (a) to prevent (re)oxidation of the copper/*OWTTE*;

1

(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;

3

*Allow ECF.*

*Award [1] for CuO with no working.*

*Alternate solution*

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

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



1

*Allow ECF.*

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

2

*Accept change colour.*

*Do not accept reduction of sample size.*

[7]

72. (a)  $n(\text{Cu}_2\text{O}) = 10.0 \times 10^3 \div 143.1 = 69.9 \text{ mol}$ ;

$n(\text{Cu}_2\text{S}) = 5.00 \times 10^3 \div 159.16 = 31.4 \text{ mol}$ ;

*Penalise failure to convert kg  $\rightarrow$  g once only.*

Cu<sub>2</sub>S is the limiting reagent;

3

*ECF from above answers.*

(b)  $n(\text{Cu}) = 6 \times n(\text{Cu}_2\text{S}) = 6 \times 31.4 = 188 \text{ mol}$ ;

$m(\text{Cu}) = 188 \times 63.55 = 11900 - 12000 \text{ g} / 11.9 - 12.0 \text{ kg}$ ;

2

*If Cu<sub>2</sub>O given in (a), allow  $3 \times n(\text{Cu}_2\text{O})$  and  $3 \times n(\text{Cu}_2\text{O}) \times 63.55$ .*

*Allow ECF from (a).*

[5]

73.  $n(\text{Fe}_2\text{O}_3) = 30 \times 10^3 \div 159.7 / n(\text{Fe}_2\text{O}_3) = 188 \text{ mol}$ ;

$n(\text{C}) = 5.0 \times 10^3 \div 12.01 / n(\text{C}) = 416 \text{ mol}$ ;

Fe<sub>2</sub>O<sub>3</sub> is the limiting reagent or implicit in calculation;

$n(\text{Fe}) = 2 \times n(\text{Fe}_2\text{O}_3) = 2 \times 188 = 376 \text{ mol}$ ;



$$m(\text{Fe}) = 376 \times 55.85 = 21 \text{ kg};$$

*Accept 2 sig. fig. or 3 sig. fig., otherwise use –1(SF).*

*Correct final answers score [5].*

*Allow ECF.*

[5]

74. (a)  $M(\text{BaSO}_4) (= 137.34 + 32.06 + 4(16.00)) = 233.40 \text{ (g mol}^{-1}\text{)}$ ;  
*Accept 233.4 but not 233*

$$n(\text{BaSO}_4) \left( = \frac{0.672 \text{ g}}{233.40 \text{ g mol}^{-1}} \right) = 0.00288 / 2.88 \times 10^{-3} \text{ (mol)}; \quad 2$$

*ECF from M value*

- (b)  $n \text{ (alkali metal sulfate)} = 0.00288 / 2.88 \times 10^{-3} \text{ (mol)}; \quad 1$   
*ECF*

(c)  $M = \left( \frac{m}{n} = \frac{0.502 \text{ g}}{0.00288 \text{ mol}} \right) 174.31 / 174.3 / 174; \quad 2$   
*ECF*

units:  $\text{g mol}^{-1}; \quad 2$

(d)  $(2(A_r) + 32 + 4(16)) = 174, \text{ thus } A_r = 39 / A_r = \left( \frac{(174 - (32 + (4 \times 16)))}{2} \right) = 39;$

*Accept answer between 38.9 and 39.2*

*ECF*

*potassium/K;*

*ECF from  $A_r$  value*

2

- (e)  $\text{K}_2\text{SO}_4(\text{aq}) + \text{BaCl}_2(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + 2\text{KCl}(\text{aq}) \quad 2$   
*Award [1] for balanced equation and [1] for state symbols*  
*ECF if another alkali metal arrived at in (d)*  
*Accept net ionic equation*  
*If no answer arrived at in (d), but correct equation given involving any alkali metal, then award [1 max]*

[9]

75. (a)  $0.600 \text{ mol Al(OH)}_3 \equiv (1.5)(0.600) \text{ mol H}_2\text{SO}_4 / 0.900 \text{ mol H}_2\text{SO}_4$   
needed, but only 0.600 mol used;  
 $\text{H}_2\text{SO}_4$  limiting reactant; 2  
*Some working must be shown in order to score the second point.*

- (b)  $0.200 \text{ mol Al}_2(\text{SO}_4)_3;$



- 68.4(g);  
*Penalize incorrect units.* 2
- (c) 0.200 mol;  
*Use ECF from (a).* 1
- (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;  
*Accept any other weak acid and correct formula.* 1

[8]