Enthalpies of Formation and Combustion of Selected Substances
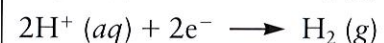
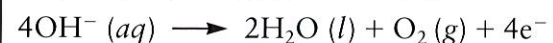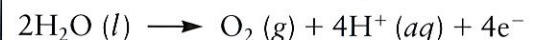| Substance	Standard enthalpy of formation kJ mol^{-1}	Standard enthalpy of combustion kJ mol^{-1}
hydrogen	–	−286
carbon (graphite)	–	−394
sulphur (rhombic)	–	−297
methane	−75	−891
ethane	−85	−1560
propane	−104	−2220
butane	−125	−2877
benzene	49	−3268
ethene	52	−1411
ethyne	227	−1300
methanol	−239	−727
ethanol	−278	−1367
propan-1-ol	−306	−2020
methanoic acid	−409	−255
ethanoic acid	−487	−876

Electrolysis Of Water

Reduction reactions at the negative electrode

$2H_2O\ (l) + 2e^- \longrightarrow H_2\ (g) + 2OH^-\ (aq)$

$2H^+\ (aq) + 2e^- \longrightarrow H_2\ (g)$

Oxidation reactions at the positive electrode

$2H_2O\ (l) \longrightarrow O_2\ (g) + 4H^+\ (aq) + 4e^-$

$4OH^-\ (aq) \longrightarrow 2H_2O\ (l) + O_2\ (g) + 4e^-$

CHAPTER 1 – Answers

1.1	32.8 g	**1.2**	0.02 mol	**1.3**	1.2 mol
1.4	8.55 g	**1.5**	0.0025 mol	**1.6**	59.6 g
1.7	0.3 mol	**1.8**	2.24 g	**1.9**	0.02 mol
1.10	48 g	**1.11**	26.9 g	**1.12**	1.5 mol
1.13	3.99 g	**1.14**	0.04 mol	**1.15**	147 g
1.16	0.8 mol	**1.17**	124.8 g	**1.18**	0.05 mol
1.19	31.8 g	**1.20**	0.03 mol	**1.21**	0.2 mol l^{-1}
1.22	0.3 mol	**1.23**	0.2 mol l^{-1}	**1.24**	40 cm^3
1.25	0.15 mol	**1.26**	0.2 mol l^{-1}	**1.27**	250 cm^3
1.28	32 g	**1.29**	0.25 mol l^{-1}	**1.30**	1.321 g
1.31	1.5 l	**1.32**	40 cm^3	**1.33**	0.5 l
1.34	7.98 g	**1.35**	0.05 mol l^{-1}	**1.36**	0.05 mol l^{-1}
1.37	0.1 mol l^{-1}	**1.38**	0.96 g	**1.39**	0.2 mol l^{-1}
1.40	25 cm^3				

CHAPTER 2 – Answers

2.1	0.5 g	**2.2**	12.7 g
2.3	0.6 g	**2.4**	3.5 g
2.5	11.5 g	**2.6**	0.4 g
2.7	7.29 g	**2.8**	2.2 g
2.9	66 g	**2.10**	1.6 g
2.11	1282 kg	**2.12**	37.5 kg
2.13	44.64 tonne	**2.14**	9612 kg
2.15	672 kg	**2.16**	2.76 × 10^3 kg
2.17	3.52 × 10^4 kg	**2.18**	3.68 tonne
2.19	1.9 × 10^5 kg	**2.20**	8.8 × 10^3 kg

CHAPTER 3 – Answers

3.1	0.5 mol l^{-1}	**3.2**	16 cm^3
3.3	6.91 g	**3.4**	300 cm^3
3.5	0.8 mol l^{-1}	**3.6**	4.15 g
3.7	0.182 mol l^{-1}	**3.8**	1.167 g
3.9	0.094 mol l^{-1}	**3.10**	0.2 mol l^{-1}
3.11	0.0584 mol l^{-1}	**3.12**	0.2 mol l^{-1}
3.13	0.36 mol l^{-1}	**3.14**	0.12 mol l^{-1}
3.15	0.021 mol l^{-1}	**3.16**	*(a)* 0.2 mol l^{-1}; *(b)* 10 times; *(c)* 2 mol l^{-1}
3.17	*(a)* 2 mol l^{-1}; *(b)* 100 cm^3	**3.18**	*(a)* 0.2 mol l^{-1}; *(b)* 0.32 mol l^{-1}
3.19	*(a)* 100 times; *(b)* 0.025 mol l^{-1}; *(c)* 2.5 mol l^{-1}		
3.20	*(a)* 0.02 mol; *(b)* 0.04 mol l^{-1}; *(c)* 0.04 mol l^{-1}		

CHAPTER 4 – Answers

4.1	*(a)*	$0.0005\,g\,s^{-1}$ $(5 \times 10^{-4}\,g\,s^{-1})$	*(b)*	$0.00015\,g\,s^{-1}$ $(1.5 \times 10^{-4}\,g\,s^{-1})$
4.2	*(a)*	$0.00325\,mol\,l^{-1}\,s^{-1}$ $(3.25 \times 10^{-3}\,mol\,l^{-1}\,s^{-1})$	*(b)*	$0.00025\,mol\,l^{-1}\,s^{-1}$ $(2.5 \times 10^{-4}\,mol\,l^{-1}\,s^{-1})$
4.3	*(a)*	$1.1\,cm^3\,s^{-1}$	*(b)*	$0.2\,cm^3\,s^{-1}$
4.4	*(a)*	$0.002\,mol\,l^{-1}\,s^{-1}$ $(2 \times 10^{-3}\,mol\,l^{-1}\,s^{-1})$	*(b)*	$0.0006\,mol\,l^{-1}\,s^{-1}$ $(6 \times 10^{-4}\,mol\,l^{-1}\,s^{-1})$
4.5	*(a)*	$0.0125\,g\,s^{-1}$	*(b)*	$0.0025\,g\,s^{-1}$ $(2.5 \times 10^{-3}\,g\,s^{-1})$
4.6	*(a)*	$1.12\,cm^3\,s^{-1}$	*(b)*	$0.08\,cm^3\,s^{-1}$
4.7	*(a)*	$0.002\,mol\,l^{-1}\,min^{-1}$ $(2 \times 10^{-3}\,mol\,l^{-1}\,min^{-1})$	*(b)*	$0.0004\,mol\,l^{-1}\,min^{-1}$ $(4 \times 10^{-4}\,mol\,l^{-1}\,min^{-1})$
4.8	*(a)*	$0.0025\,g\,s^{-1}$ $(2.5 \times 10^{-3}\,g\,s^{-1})$	*(b)*	$0.003\,g\,s^{-1}$ $(3 \times 10^{-3}\,g\,s^{-1})$
4.9	*(a)*	$0.5\,cm^3\,s^{-1}$	*(b)*	$0.1\,cm^3\,s^{-1}$
4.10	*(a)*	$0.000096\,mol\,l^{-1}\,s^{-1}$ $(9.6 \times 10^{-5}\,mol\,l^{-1}\,s^{-1})$	*(b)*	$0.00005\,mol\,l^{-1}\,s^{-1}$ $(5 \times 10^{-5}\,mol\,l^{-1}\,s^{-1})$
4.11	*(a)*	$0.37\,mol\,l^{-1}$	*(b)*	$50\,s$
4.12	*(a)*	$25\,s$	*(b)*	$33\,°C$
	(c)	$0.004\,s^{-1}$, $0.008\,s^{-1}$, $0.016\,s^{-1}$ and $0.032\,s^{-1}$ respectively. The rate doubles with each 10 °C rise in temperature.		
4.13	*(a)*	$0.32\,mol\,l^{-1}$	*(b)*	$40\,s$
4.14	*(a)*	$25\,°C$	*(b)*	$25\,s$
4.15	*(a)*	$62.5\,s$	*(b)*	$0.0084\,mol\,l^{-1}$

CHAPTER 5 – Answers

Answers have, in some cases, been rounded to 3 significant figures.

5.1	*(a)* Pb in excess; *(b)* 0.05 g	**5.2**	*(a)* $CaCO_3$ in excess; *(b)* 4.4 g
5.3	*(a)* KI in excess; *(b)* 11.1 g	**5.4**	*(a)* Na_2CO_3 in excess; *(b)* 1.1 g
5.5	*(a)* NaOH in excess; *(b)* 1.56 g	**5.6**	*(a)* $MgCl_2$ in excess; *(b)* 0.322 g
5.7	*(a)* $BaCl_2$ in excess; *(b)* 0.934 g	**5.8**	*(a)* $(NH_4)_2SO_4$ in excess; *(b)* 1.02 g
5.9	*(a)* FeS in excess; *(b)* 1.36 g	**5.10**	*(a)* CuO in excess; *(b)* 0.636 g; *(c)* 1.92 g

CHAPTER 6 – Answers

Answers have been rounded to a **maximum** of 3 significant figures.

Note: In Problems 6.1 to 6.5, the questions state whether heat is given out or absorbed, and simply ask for the amount of heat. So, strictly speaking, the answers do not need a + or − sign, as the direction of the enthalpy change is given in the question. However, signs are given in these answers, to emphasise whether the process is exothermic or endothermic.

6.1	$-3.34\,kJ$	**6.2**	$-3.34\,kJ$	**6.3**	$+2.09\,kJ$
6.4	$-1.25\,kJ$	**6.5**	$-39.7\,kJ$	**6.6**	$+167\,kJ\,mol^{-1}$
6.7	$-188\,kJ\,mol^{-1}$	**6.8**	$-334\,kJ\,mol^{-1}$	**6.9**	$-167\,kJ\,mol^{-1}$
6.10	$+62.7\,kJ\,mol^{-1}$	**6.11**	$-669\,kJ\,mol^{-1}$	**6.12**	$-25.1\,kJ\,mol^{-1}$
6.13	$-836\,kJ\,mol^{-1}$	**6.14**	$+25.1\,kJ\,mol^{-1}$	**6.15**	$-1340\,kJ\,mol^{-1}$
6.16	$-41.8\,kJ\,mol^{-1}$	**6.17**	$-2090\,kJ\,mol^{-1}$	**6.18**	$+16.7\,kJ\,mol^{-1}$
6.19	$-2660\,kJ\,mol^{-1}$	**6.20**	$+33.4\,kJ\,mol^{-1}$	**6.21**	3.92 g
6.22	0.422 g	**6.23**	0.295 °C	**6.24**	0.335 g
6.25	6.6 °C rise	**6.26**	10.7 °C	**6.27**	5.96 g
6.28	33.1 g	**6.29**	11.1 g	**6.30**	13.5 g
6.31	$-58.5\,kJ\,mol^{-1}$	**6.32**	$-57.7\,kJ\,mol^{-1}$	**6.33**	$-56.8\,kJ\,mol^{-1}$
6.34	$-56.8\,kJ\,mol^{-1}$	**6.35**	$-57.1\,kJ\,mol^{-1}$	**6.36**	3.43 °C
6.37	6.85 °C	**6.38**	3.43 °C	**6.39**	3.43 °C
6.40	9.14 °C				

CHAPTER 7 – Answers

The answers below are expressed to a **maximum** of 3 significant figures.

7.1	1.20×10^{24}	**7.2**	1.81×10^{24}
7.3	7.22×10^{23}	**7.4**	0.002
7.5	0.0375	**7.6**	1.20×10^{23}
7.7	1.2×10^{23}	**7.8**	0.6
7.9	9.03×10^{23}	**7.10**	0.04
7.11	2.41×10^{22}	**7.12**	1×10^{-4}
7.13	4.06×10^{24}	**7.14**	2
7.15	7.22×10^{23}	**7.16**	3.33
7.17	4.33×10^{24}	**7.18**	2.71×10^{23}
7.19	0.05 mol	**7.20**	1.44×10^{23}
7.21	6.02×10^{21}	**7.22**	0.3 g
7.23	3.01×10^{22}	**7.24**	0.416 g
7.25	3.27×10^{-22} g	**7.26**	1.20×10^{23}
7.27	0.0486 g	**7.28**	2.41×10^{24}
7.29	0.14 g	**7.30**	7.31×10^{-23} g
7.31	1.08×10^{23}	**7.32**	0.0025 g
7.33	7.22×10^{22}	**7.34**	0.32 g
7.35	*(a)* 9.63×10^{22}; *(b)* 4.82×10^{22}	**7.36**	7.97×10^{-23} g
7.37	9.63×10^{22}	**7.38**	9.03×10^{22}
7.39	7.22×10^{23}	**7.40**	0.068 g

CHAPTER 8 – Answers

Note: The answers below are given to a **maximum** of three significant figures.

8.1	$22.2\,l$	**8.2**	$1.28\,g\,l^{-1}$
8.3	N_2: $0.237\,l$; H_2: $0.234\,l$	**8.4**	15.9
8.5	$0.525\,g\,l^{-1}$	**8.6**	$22.4\,l$
8.7	64.0	**8.8**	$0.52\,g\,l^{-1}$
8.9	30.0; ethane, C_2H_6	**8.10**	32.1; oxygen, O_2
8.11	$22.4\,l$	**8.12**	0.0236 g
8.13	$3.24\,l$	**8.14**	$100\,l$
8.15	185 g	**8.16**	$0.0449\,l$
8.17	$24.3\,l$	**8.18**	1100 g
8.19	$0.0248\,l$	**8.20**	$24.3\,l$
8.21	*(a)* $41.2\,l$; *(b)* O_2: $0.777\,g\,l^{-1}$; CO_2: $1.07\,g\,l^{-1}$	**8.22**	$24\,l$; 38.0
8.23	15.8	**8.24**	31.8
8.25	0.0802 g		

CHAPTER 9 – Answers

9.1	*(a)* O_2; *(b)* $100\,cm^2\,O_2$ and $100\,cm^3\,CO_2$	**9.2**	*(a)* CO; *(b)* $40\,cm^3\,CO_2$ and $10\,cm^3\,CO$
9.3	$60\,l\,CO_2$ and $40\,l\,O_2$	**9.4**	$1200\,l\,CO_2$ and $3200\,l\,O_2$
9.5	$400\,cm^3\,CO_2$, $600\,cm^3\,H_2O$ and $1300\,cm^3\,O_2$	**9.6**	$100\,l\,N_2$, $200\,l\,H_2O$ and $300\,l\,O_2$
9.7	$600\,l\,CO_2$, $1025\,l\,O_2$	**9.8**	*(a)* $2.4 \times 10^5\,l\,CO_2$; *(b)* $5.2 \times 10^5\,l\,H_2$
9.9	$5 \times 10^5\,l\,CCl_4$, $5 \times 10^5\,l\,S_2Cl_2$, $10^6\,l\,Cl_2$	**9.10**	$4.5 \times 10^5\,l$

CHAPTER 10 – Answers

10.1	90 l	**10.2**	1.1 l
10.3	272 g	**10.4**	320 l
10.5	10.9 g	**10.6**	4.4 l
10.7	40 000 l ($4 \times 10^4 l$)	**10.8**	798 g
10.9	3 l	**10.10**	234 kg

CHAPTER 11 – Answers

Note: The answers below have been rounded to a maximum of three significant figures.

11.1	11.2 g	**11.2**	13.4 g
11.3	0.45 g	**11.4**	33.5 g
11.5	5.75 g	**11.6**	7.14×10^4 kg
11.7	27.6 kg	**11.8**	7.20×10^4 kg
11.9	6.51×10^3 kg	**11.10**	666 kg
11.11	*(a)* 25.6 g; *(b)* 75%	**11.12**	40%
11.13	75%	**11.14**	75%
11.15	*(a)* 4.24 g; *(b)* 80%	**11.16**	60%
11.17	70%	**11.18**	60%
11.19	*(a)* 4.185 kg; *(b)* 90%	**11.20**	*(a)* 3.99×10^4 kg; *(b)* 60%

CHAPTER 12 – Answers

Note: In some cases, a calculated enthalpy change may differ slightly from the accepted value given in Appendix 2 or the SQA Data Book. This is because the original data are rounded to whole numbers and, in the calculation, any rounding error may be multiplied, resulting in a (very) small difference from the accepted value.

12.1	-891 kJ mol^{-1}	**12.2**	-1561 kJ mol^{-1}	**12.3**	-86 kJ mol^{-1}
12.4	-2222 kJ mol^{-1}	**12.5**	-129 kJ mol^{-1}	**12.6**	-1368 kJ mol^{-1}
12.7	-484 kJ mol^{-1}	**12.8**	-306 kJ mol^{-1}	**12.9**	-3271 kJ mol^{-1}
12.10	$+226$ kJ mol^{-1}	**12.11**	-425 kJ mol^{-1}	**12.12**	-491 kJ mol^{-1}
12.13	-137 kJ mol^{-1}	**12.14**	-79 kJ mol^{-1}	**12.15**	-312 kJ mol^{-1}
12.16	-412 kJ mol^{-1}	**12.17**	$+376$ kJ mol^{-1}	**12.18**	$+776$ kJ mol^{-1}
12.19	-409 kJ mol^{-1}	**12.20**	-5120 kJ mol^{-1}		

CHAPTER 13 – Answers

Note 1: Where concentrations are below 0.001 mol l^{-1} they are give only as a power of 10; concentrations of 0.001 mol l^{-1} or above are given both as a decimal fraction and as a power of 10. Where a concentration is 1 mol l^{-1}, this is given as 10^0 as well as 1, although in practice only the latter would be used.

Note 2: In some of Problems 13.31–13.40, where a dilution is by a factor of 100, the answers give the **two most obvious** ways of carrying out the dilution, in one or two steps. There may be **other** quite correct answers which are not given. The answers to such questions are marked with an asterisk (*).

13.1	3	**13.2**	6
13.3	5	**13.4**	0
13.5	4	**13.6**	8
13.7	11	**13.8**	4
13.9	7	**13.10**	14
13.11	10^{-5} mol l^{-1}	**13.12**	10^{-3} mol l^{-1} (or 0.001 mol l^{-1})

13.13	10^{-7} mol l^{-1}	**13.14**	10^{-13} mol l^{-1}
13.15	10^{-2} mol l^{-1} or 0.01 mol l^{-1}	**13.16**	10^0 mol l^{-1} (more normally expressed as 1 mol l^{-1})
13.17	10^{-4} mol l^{-1}	**13.18**	10^{-10} mol l^{-1}
13.19	10^{-12} mol l^{-1}	**13.20**	10^{-1} mol l^{-1} or 0.1 mol l^{-1}
13.21	*(a)* 10^{-10} mol l^{-1}; *(b)* 10	**13.22**	*(a)* 10^{-6} mol l^{-1}; *(b)* 10^{-8} mol l^{-1}
13.23	*(a)* 10^{-12} mol l^{-1}; *(b)* 12	**13.24**	*(a)* 10^{-5} mol l^{-1}; *(b)* 10^{-9} mol l^{-1}
13.25	*(a)* 10^{-5} mol l^{-1}; *(b)* 5		
13.26	*(a)* 10^{-14} mol l^{-1}; *(b)* 10^0 mol l^{-1} (more normally expressed as 1 mol l^{-1})		
13.27	*(a)* 10^{-11} mol l^{-1}; *(b)* 11		
13.28	*(a)* 10^{-13} mol l^{-1}; *(b)* 10^{-1} mol l^{-1} (0.1 mol l^{-1})		
13.29	*(a)* 10^{-1} mol l^{-1} (0.1 mol l^{-1}); *(b)* 1		
13.30	*(a)* 10^{-3} mol l^{-1} (or 0.001 mol l^{-1}); *(b)* 10^{-11} mol l^{-1}		
13.31	*(a)* 0; *(b)* take 10 cm^3 of original solution and dilute to 100 cm^3		
13.32	*(a)* 2; *(b)* take 5 cm^3 of original solution and dilute to 50 cm^3		
13.33	*(a)* 1; *(b)* take 25 cm^3 of original solution and dilute to 250 cm^3		

13.34* *(a)* 1
(b) take 5 cm^3 of original solution and dilute to 500 cm^3 **or** take the whole 10 cm^3 of the original solution, dilute to 100 cm^3 and then take 50 cm^3 of this diluted solution and further dilute to 500 cm^3

13.35* *(a)* 0
(b) take 10 cm^3 of original solution and dilute to 1 litre **or** take the whole 50 cm^3 of the original solution, dilute to 500 cm^3 and then take 100 cm^3 of this diluted solution and further dilute to 1 litre.

13.36 *(a)* 14; *(b)* take 5 cm^3 of original solution and dilute to 50 cm^3

13.37 *(a)* 13; *(b)* take 10 cm^3 of original solution and dilute to 100 cm^3

13.38 *(a)* 12; *(b)* take 25 cm^3 of original solution and dilute to 250 cm^3

13.39* *(a)* 14
(b) take 10 cm^3 of original solution and dilute to 1 litre **or** take the whole 50 cm^3 of the original solution, dilute to 500 cm^3 and then take 100 cm^3 of this diluted solution and further dilute to 1 litre.

13.40* *(a)* 12
(b) take 5 cm^3 of original solution and dilute to 500 cm^3 **or** take the whole 10 cm^3 of the original solution, dilute to 100 cm^3 and then take 50 cm^3 of this diluted solution and further dilute to 500 cm^3.

CHAPTER 14 – Answers

14.1	50 cm^3	**14.2**	16 cm^3
14.3	0.0625 mol l^{-1}	**14.4**	40 cm^3
14.5	0.08 mol l^{-1}	**14.6**	0.05 mol l^{-1}
14.7	0.4 mol l^{-1}	**14.8**	18 cm^3
14.9	20 cm^3	**14.10**	38.4 cm^3

CHAPTER 15 – Answers

All answers have been rounded to three significant figures.

15.1	96,300 C	**15.2**	96,500 C	**15.3**	96,600 C
15.4	96,300 C	**15.5**	96,500 C	**15.6**	96,600 C
15.7	96,500 C	**15.8**	96,600 C	**15.9**	95,200 C
15.10	96,600 C	**15.11**	96,400 C	**15.12**	96,400 C
15.13	96,500 C	**15.14**	96,600 C	**15.15**	96,400 C
15.16	96,300 C	**15.17**	96,500 C	**15.18**	96,700 C

15.19	96,800 C	**15.20**	96,600 C	**15.21**	0.118 g
15.22	0.0554 g	**15.23**	0.302 g	**15.24**	0.00311 g
15.25	3.09 g				
15.26	(a) 0.00280 g H_2; (b) 0.0224 g O_2				
15.27	0.168 g	**15.28**	(a) 0.00373 g H_2; (b) 0.0298 g O_2		
15.29	592 g	**15.30**	806 kg	**15.31**	42.9 kg
15.32	13.1 kg	**15.33**	725 kg	**15.34**	1.29 kg
15.35	376 kg	**15.36**	31.1 cm^3	**15.37**	239 cm^3
15.38	15.5 cm^3	**15.39**	23.3 cm^3	**15.40**	119 cm^3
15.41	29.4 cm^3	**15.42**	77.7 cm^3	**15.43**	93.3 cm^3
15.44	88.6 cm^3	**15.45**	27.4 cm^3	**15.46**	643 minutes
15.47	0.402 A	**15.48**	0.268 A	**15.49**	965 minutes
15.50	32.2 minutes	**15.51**	3.22 A	**15.52**	1.61 A
15.53	322 minutes	**15.54**	0.965 A	**15.55**	804 minutes
15.56	21.4 hours	**15.57**	2.14×10^3 A	**15.58**	149 minutes
15.59	1.79×10^4 A	**15.60**	2.68×10^3 A	**15.61**	2+
15.62	3+	**15.63**	3+	**15.64**	1+
15.65	2+				

CHAPTER 16 – Answers

16.1	4 days	**16.2**	56 hours	**16.3**	16 counts min^{-1}
16.4	2.5 years	**16.5**	24.9 days	**16.6**	$\frac{1}{32}$
16.7	5 minutes	**16.8**	21 s	**16.9**	0.0625 g
16.10	1.2 hours	**16.11**	24 s	**16.12**	25%
16.13	15 hours	**16.14**	840 days	**16.15**	$\frac{1}{16}$
16.16	12.3 years	**16.17**	49.8 hours	**16.18**	3.125%
16.19	3×10^5 years	**16.20**	5.2×10^9 years	**16.21**	11,140 years
16.22	4 counts min^{-1}	**16.23**	27,850 years	**16.24**	16,710 years
16.25	22,280 years				