$n_2 = 3.944 \times 10^{-3}$ *mol*
$n_1 = 0.56 \times 0.2 = 0.112$ *mol*

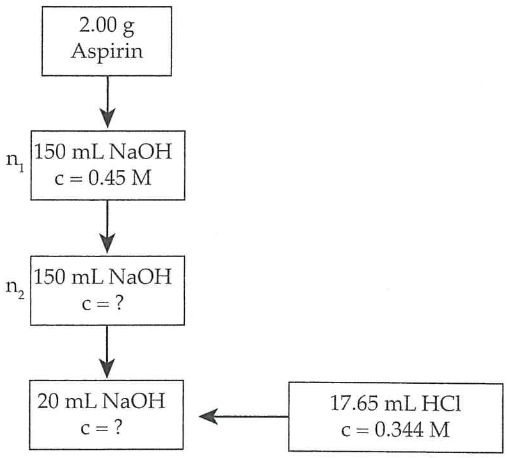
Amount of HCl used $= n_1 - n_2$
$= 0.112 - 3.944 \times 10^{-3}$
$= 0.1081$ *mol*

Ratio MgO : HCl is 2:1 so
$n(MgO) = ½ \times 0.1081 = 0.05403$ *mol*

$m(MgO) = 0.05403 \times (24.31 + 16)$
$= 2.18$ *g*
$\% \text{ of } MgO = \frac{2.18}{4.47} = \times 100\%$

% Purity = 48.7%

30.
(i)



$n(HCl) = 0.344 \times 0.01765$
$= 6.072 \times 10^{-3}$ *mol*
Ratio NaOH to HCl is 1:1 so
$n(NaOH) = 6.072 \times 10^{-3}$ *mol in 20 mL*
$\therefore$ *in 150 mL* $n(NaOH) =$
$6.072 \times 10^{-3} \times \frac{150}{20} = 0.0455$ *mol*
$n_2 = 0.0445$ *mol*
$n_1 = 0.45 \times 0.15 = 0.0675$ *mol*

Amount of HCl used $= n_1 - n_2$
$= 0.0675 - 0.0455$
$= 0.0220$ *mol*

Ratio Aspirin to NaOH is 1:2
So $n(Aspirin) = ½\, n(NaOH)$
$= 0.0110$ *mol*
$m(Aspirin) = 0.0110 \times 168.144 = 1.85$ *g*
$\% \text{ of Aspirin} = \frac{1.85}{2.00} \times 100\%$

% Purity = 92.5%

(ii) *This value exceeds the 90% set value and so conforms to the law.*

Chapter 3. Redox Reactions

Set 1 Oxidation and Reduction

1.	*Species Oxidised*	*Na*
	Species reduced	O_2
	Oxidant	O_2
	Reductant	*Na*
2.	*Species Oxidised*	*Zn*
	Species reduced	Cr^{3+}
	Oxidant	Cr^{3+}
	Reductant	*Zn*
3.	*Species Oxidised*	H_2
	Species reduced	O_2
	Oxidant	O_2
	Reductant	H_2
4.	*Species Oxidised*	H_2S
	Species reduced	$Cr_2O_7^{2-}$
	Oxidant	$Cr_2O_7^{2-}$
	Reductant	H_2S
5.	*Species Oxidised*	Cl^-
	Species reduced	H_2O_2
	(ON of Cl is $^+1$ *in HClO)*	
	Oxidant	H_2O_2
	Reductant	Cl^-
6.	*4+ 7. 5+ 8. 4+ 9. 2+ 10. 7+*	
7.	*Species Oxidised*	*HBr*
	Species reduced	H_2SO_4
8.	*Species Oxidised*	$SnCl_2$
	Species reduced	O_2
9.	*Species Oxidised*	Fe^{2+}
	Species reduced	$Cr_2O_7^{2-}$
10.	*Species Oxidised*	*None*
	Species reduced	*None*
11.	*Species Oxidised*	I^-
	Species reduced	Cl_2

Set 2 Oxidation

Multiple Choice Answers

1. d, 2. b, 3. d, 4. b, 5. c, 6. c, 7.a, 8. b, 9. a, 10. a, 11. e, 12. b

Written Answers

1.
(a) S = +6
(b) Mn = +7
(c) N = +5
(d) C = +4,
(e) N = +4
(f) S = +6
(g) S = +6
(h) S = -2

2.
(a) H = +1, S = -2
(b) P = +5, O = -2
(c) Na = +1, P = -3

(d) Cr = +3, O = -2, H = +1
(e) S = +6, O = -2
(f) Ba = +2, Mn = +7, O = -2
(g) S = +4, O = -2
(h) H = +1, O = -2
(i) Al = +3, Cl = -1
(j) K = +1, N = +5, O = -2

3.

a) (i) $Ni + I_2$ YES
(ii) $Ag + Au^{3+}$ NO
(iii) $Al + Cd^{2+}$ YES
(iv) $Cl^- + Br_2$ NO

b) Order is C^{2+}, B^{3+} A. Redox table would be:

A^+	A
B^{3+}	B^{2+}
C^{2+}	C

4.

(a) S in SO_2 is reduced from +4 to 0.
(b) Cl in HCl is oxidised from –1 to 0.
(c) Cl in Cl_2 is reduced from 0 to –1.
(d) Cu in CuO is reduced from +2 to 0.

5.

Oxidising agent	Reducing agent	Redox reaction?
a) MnO_4^-	H_2O_2	Redox
b)		**Not a redox**
c) I_2	$S_2O_3^{2-}$	Redox
d) N_2	H_2	Redox
e) H_2O	C	Redox
f) NO_3^-	Fe^{2+}	Redox
g)		**Not a redox**
h)		**Not a redox**
i)		**Not a redox**
j) NaClO	Na_2SO_3	Redox
k) CH_3OH	Na	Redox
l)		**Not a redox**
m) H_2SO_4	Zn	Redox
n)		**Not a redox**
o) MnO_2	NaCl	Redox
p) H_2SO_4	HBr	Redox
q) HNO_3	HCl	Redox
r) HNO_3	CuS	Redox

6.

(a) $I_2 + 6H_2O \rightarrow 2IO_3^- + 12H^+ + 10e^-$
(b) $HClO + H^+ + 2e^- \rightarrow Cl^- + H_2O$
(c) $NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$
(d) $NO_3^- + 2H^+ + e^- \rightarrow NO_2 + H_2O$
(e) $H_3PO_3 + H_2O \rightarrow H_3PO_4 + 2H^+ + 2e^-$
(f) $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$
(g) $SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^-$
(h) $C_2O_4^{2-} + 2H_2O \rightarrow 2CO_3^{2-} + 4H^+ + 2e^-$
(i) $SO_3^{2-} + H_2O \rightarrow SO_4^{2-} + 2H^+ + 2e^-$
(j) $H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-$

7.

(a) Oxygen
(b) Nitrogen
(c) Gold
(d) Chlorine
(e) Bromine

8.

(a) $4HCl + O_2 \rightarrow 2H_2O + 2Cl_2$
(b) $Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O$

9. ZnO; ZnH_2; ZnI_2

10.

(a) PCl_3 or PCl_5
(b) PCl_5
(c) $CuCl_2$
(d) $I_2 + Cl^-$

11.

(a) $Cu_2SO_4 \rightarrow CuSO_4 + Cu$
(b) $Hg_2Cl_2 \rightarrow HgCl_2 + Hg$
(c) $2\ NO_2 + H_2O \rightarrow HNO_3 + HNO_2$
(d) $Cl_2 + H_2O \rightarrow HCl + HOCl$

Set 3 Redox Reactions

Multiple Choice Answers

1. d, 2. c, 3. a, 4. c, 5. e, 6. c, 7. e, 8. c, 9. e, 10. d.

Calculations

1.

(i) $(Fe^{2+} \rightarrow Fe^{3+} + e^-) \times 5$
$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$
$5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow$
$5Fe^{3+} + Mn^{2+} + 4H_2O$ (Redox)

(ii) $\therefore n(MnO_4^-) = c \times V = 0.10 \times 0.0250$
$= 0.00250$ mol
$\therefore n(Fe^{2+}) = 5 \therefore n(MnO_4^-) = 5 \times 0.00250$
$= 0.0125$ mol
$\therefore [Fe^{2+}] = n/V = (0.0125/0.020)$
$= 0.625$ mol L^{-1}

2. Initial volume (commercial H_2O_2) = 10.0 mL
The 10.0 mL is made up to 100.0 mL
Volume of the diluted H_2O_2 used for titration = 10.0 mL
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$
$(H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-) \times 3$
$Cr_2O_7^{2-} + 8H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O +$

$3O_2$ — Redox
$n\ (Cr_2O_7^{2-}) = c \times V = 0.0030\ mol$
$\therefore n\ (H_2O_2) = 3 \times 0.0030 = 0.0090\ mol$
20.0 mL of diluted solution is equal to 0.0090 mol
The original volume of commercial H_2O_2 = 10.0 mL
Volume of water added = 100.0 mL and so the final volume is 110.0 mL = 0.110 L
Volume of diluted H_2O_2 used for titration = 20.0 mL = 0.020 L
Based on the reacting mol ratio, the mols of diluted H_2O_2 used in titration is equal to Number mols of $K_2Cr_2O_7$ used in each titration × 3 = 0.0090 mol.
$\therefore$ concentration of H_2O_2 in the original solution = $[(0.0090 \times 0.110)/0.02]$
$= 4.95\ mol\ L^{-1}$

3. $(MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O) \times 2$
$(H_2C_2O_4 \rightarrow 2CO_2 + 2H^+ + 2e^-) \times 5$
$2MnO_4^- + 6H^+ + 5H_2C_2O_4 \rightarrow$
$2Mn^{2+} + 8H_2O + 10CO_2$ — Redox
$n\ (MnO_4^-) = c \times V = 0.11 \times 0.010$
$= 0.0011\ mol$
$\therefore n\ (H_2C_2O_4) = [(0.0011 \times 5)/2]$
$= 2.75 \times 10^{-3}\ mol$
$\therefore c\ (H_2C_2O_4) = (n\ /V)$
$= (2.75 \times 10^{-3}/\ 0.020) = 1.375 \times 10^{-1}\ mol\ L^{-1}$

4. $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$
$(Fe^{2+} \rightarrow Fe^{3+} + e^-) \times 6$
$Cr_2O_7^{2-} + 6Fe^{2+} + 14H^+ \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$ — Redox
$n(Fe^{2+}) = cV = 0.01\ mol$
$\therefore n\ (Cr_2O_7^{2-}) = 1.67 \times 10^{-3}\ mol$
$\therefore n\ (Cr) = 2 \times 1.67 \times 10^{-3}\ mol$
$\therefore m\ (Cr) = 2 \times 1.67 \times 10^{-3} \times 52.0 = 0.173\ g$
$\%\ Cr = [(0.173/1.70) \times 100] = 10.2\%$

5. $c(H_2C_2O_4) = (n/V) = [(12.6/42.036)/1.0]$
$= 0.14\ mol\ L^{-1}$
$(MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O) \times 2$
$(H_2C_2O_4 \rightarrow 2CO_2 + 2H^+ + 2e^-) \times 5$
$2MnO_4^- + 6H^+ + 5H_2C_2O_4 \rightarrow$
$2Mn^{2+} + 8H_2O + 10CO_2$ – Redox
$n\ (H_2C_2O_4$ in each titration$) = c \times V$
$= 0.14 \times 0.020 = 2.8 \times 10^{-3}\ mol$
$\therefore n\ (MnO_4^-) = [(2.8 \times 10^{-3} \times 2)/5]$
$= 1.12 \times 10^{-3}\ mol$
$\therefore c\ [MnO_4^-] = (n/V) = (1.12 \times 10^{-3}/0.025)$
$= 4.48 \times 10^{-2}\ mol\ L^{-1}$

6. $(MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O) \times 2$
$(H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-) \times 5$
$2MnO_4^- + 6H^+ + 5H_2O_2 \rightarrow$
$2Mn^{2+} + 8H_2O + 5O_2$ – Redox
$n\ (MnO_4^-) = c \times V = 0.02 \times 0.04$
$= 8.00 \times 10^{-4}\ mol$
$\therefore [H_2O_2] = [(8.00 \times 10^{-4} \times 5)/2]$
$= 2.0 \times 10^{-3}\ mol$
$\therefore c\ [H_2O_2] = (2.0 \times 10^{-3}/0.002) = 1.0\ mol\ L^{-1}$
Pressure of 755 mm Hg = 100 × 755/760 = 99.34 kPa
$V = (nRT/P) = (0.002 \times 8.314 \times 308)/99.34$
Volume of oxygen = (5.122/100.633)
= 0.0516 L = 51.6 mL

7. $(MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O) \times 2$
$(H_2C_2O_4 \rightarrow 2H^+ + 2CO_2 + 2e^-) \times 5$
$2MnO_4^- + 6H^+ + 5H_2C_2O_4 \rightarrow$
$2Mn^{2+} + 8H_2O + 10CO_2$ — Redox
$n\ (H_2C_2O_4) = c\ V = 0.0022\ mol$
$\therefore n\ (KMnO_4) = [(0.0022 \times 2)/5]$
$= 0.00088\ mol$
$\therefore c\ (KMnO_4) = (n/V) = (0.00088/0.009)$
$= 0.098\ mol\ L^{-1}$

8. The redox equation is
$Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$
$n\ (Fe^{2+}) = cV = 0.05 \times 0.02 = 0.001\ mol$
$\therefore n\ (Cr_2O_7^{2-}) = [(0.001 \times 1)/6] = 1.67 \times 10^{-4}\ mol$
$\therefore c\ (Cr_2O_7^{2-}) = (1.67 \times 10^{-4}/7.5 \times 10^{-3})$
$= 0.021\ mol\ L^{-1}$

9. The redox equation is $MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$
$\therefore n\ (MnO_4^-) = 0.0010 \times 0.0015$
$= 0.0000015\ mol = 1.5 \times 10^{-6}\ mol$
$\therefore n\ (FeSO_4) = (1.5 \times 10^{-6}\ mol) \times 5$
$= 7.5 \times 10^{-6}\ mol$
$\therefore c\ (FeSO_4) = (n/V) = (7.5 \times 10^{-6}/0.05)$
$= 0.00015\ M = 1.5 \times 10^{-4}\ mol\ L^{-1}$

10. $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$
$(H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-) \times 3$
$Cr_2O_7^{2-} + 8H^+ + 3H_2O_2 \rightarrow$
$2Cr^{3+} + 7H_2O + 3O_2$ – Redox

(a) $n\ (H_2O_2) = (1.0/\ 34.016) = 0.0294\ mol$
$\therefore n\ (Cr_2O_7^{2-}) = (0.0294/3) = 0.0098\ mol$
$m\ (K_2Cr_2O_7) = 0.0098 \times 294.2 = 2.88\ g$

(b) $n\ (O_2) = n\ (H_2O_2) = 0.0294\ mol$
$V(O_2\ @STP) = 0.0294 \times 22.71 = 0.659\ L$

11. $(C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-) \times 5$
$(MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O) \times 2$
$5C_2O_4^{2-}(aq) + 2MnO_4^-(aq) + 16H^+(aq) \rightarrow$
$10CO_2(g) + 2Mn^{2+}(aq) + 8H_2O(l)$

(a) Titre values of $KMnO_4$ = 24.48 mL, 24.54 mL, 24.48 mL = Average = 24.50 mL

(b) $n\ (KMnO_4) = cV = 0.020 \times 0.02450$
$= 4.90 \times 10^{-4}\ mol$
$\therefore n\ (C_2O_4^{2-}) = [(4.9 \times 10^{-4} \times 5)\ /2]$
$= 1.225 \times 10^{-3}\ mol$
$\therefore [C_2O_4^{2-}] = (n\ /V) = (1.225 \times 10^{-3}/\ 0.0250)$
$= 0.049\ mol\ L^{-1}$

(c) $n\ (CO_2) = n\ (KMnO_4 \times 5) = 4.9 \times 10^{-4} \times 5$
$= 2.45 \times 10^{-3}\ mol$
$V(CO_2\ @\ STP) = 2.45 \times 10^{-3} \times 22.71$
$= 0.056\ L = 55.6\ mL$

12. *The redox equation is* $5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$
$n(KMnO_4) = cV = 0.020 \times 0.020$
$= 4.0 \times 10^{-4}$ *mol*
$n(Fe^{2+}) = 5 \times n(MnO^{4-}) = 5 \times 0.0004$
$= 0.002$ *mol*
$[Fe^{2+}] = (n/V) = (0.002/0.025)$
$= 0.080$ *mol* L^{-1}
$n(Fe^{2+}$ *in* $0.50\ L) = 0.08 \times 0.500$
$= 0.040$ *mol*
$m(Fe^{2+}) = m(Fe) = 0.040 \times 55.85 = 2.234\ g$
$\therefore$ *% of Fe in the ore* $= [(2.234/4) \times 100]$
$= 55.9\%$

13. *The redox equation is*
$2MnO_4^- + 6H^+ + 5H_2O_2 \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$

(a) $n(MnO_4^-$ *used in the titration*$) = cV$
$= 0.016 \times 0.02020 = 3.232 \times 10^{-4}$ *mol*
$\therefore n(H_2O_2) = [(3.232 \times 10^{-4} \times 5)/2]$
$= 8.08 \times 10^{-4}$ *mol*
$n(H_2O_2)$ *in* $0.020\ L = 8.08 \times 10^{-4}$ *mol*
$\therefore n(H_2O_2)$ *in the stock solution of 1.0 L)*
$= [(8.08 \times 10^{-4} \times 1000)/20] = 0.0404$ *mol*
$\therefore n(H_2O_2)$ *in the 40.0 mL of commercial solution* $= 0.0404$ *mol*
$\therefore c[H_2O_2]$ *in the commercial solution*
$= (n/V) = (0.0404/0.040) = 1.01$ *mol* L^{-1}

(b) *%* H_2O_2 *by mass in 40.0 mL of the commercial solution (40.0 g of the solution)*
= (mass of H_2O_2 *present in 40.0 mL/mass of 40.0 mL of the solution)* $\times 100$
$= [(1.01 \times 34.016)/40] \times 100$
$= (34.36/40) \times 100$
$= 85.9\%$

(c) *Since 1 mol of* H_2O_2 *releases 1 mol of oxygen gas according to this equation,*
1.01 mol in 1.0 L will release 1.01mol of oxygen gas which is $1.01 \times 22.71 = 22.94$ *L*
$\therefore$ *Volume strength of the solution = 22.9.*

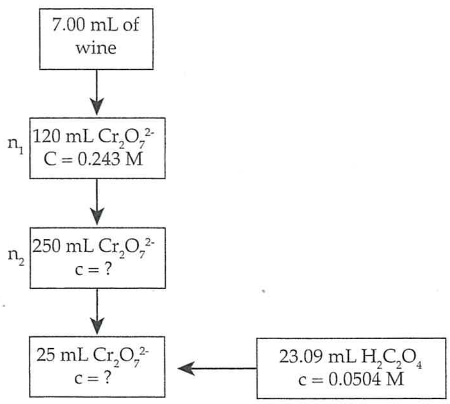
Redox Back-Titrations

14.

(a) $3C_2O_4^{2-} + Cr_2O_7^{2-} + 14H^+ \rightarrow 6CO_2 + 2Cr^{3+} + 7H_2O$

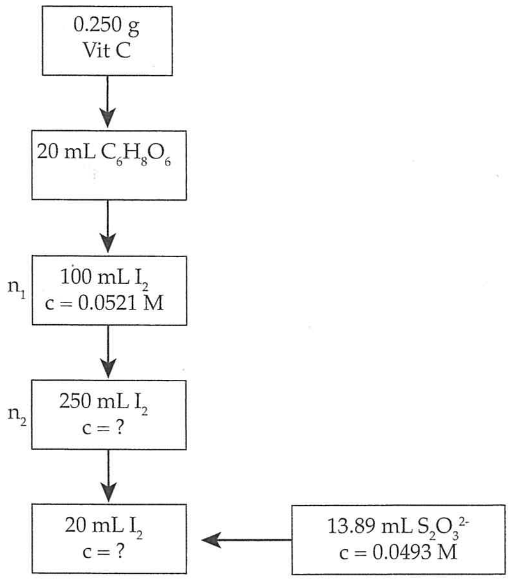
(b) *Average titre = 23.09 mL*

(c) *Flow-chart:*



$n(Cr_2O_7^{2-})$ *added* $= 0.120 \times 0.243$
$= 0.02916$ *mol*
$n_1 = 0.02916$ *mol*
$n(H_2C_2O_4)$ *in titre* $= 0.0504 \times 0.02309$
$= 1.165 \times 10^{-3}$ *mol*
From above: $n(Cr_2O_7^{2-}) = 1/3 \times n(H_2C_2O_4)$
$= 3.879 \times 10^{-4}$ *mol in 25 mL*
Hence in 250 mL $n(Cr_2O_7^{2-})$
$= 3.879 \times 10^{-4} \times \frac{250}{25}$
$= 3.879 \times 10^{-3}$ *mol*
$n_2 = 3.879 \times 10^{-3}$ *mol*
$n(Cr_2O_7^{2-})$ *reacted* $= n_1 - n_2$
$= 0.02916 - 3.879 \times 10^{-3} = 0.0253$ *mol.*
Reaction with alcohol: $n(CH_3CH_2OH)$
$= 3/2 \times n(Cr_2O_7^{2-}) = 3/2 \times 0.0253$
i.e. 0.0379 mol alcohol is in 7 mL of solution.
$c(CH_3CH_2OH) = n/V = 0.0379/0.007$
$= 5.41$ *mol* L^{-1}.

15.



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

(b) $C_6H_8O_6(aq) + I_2(aq) \rightarrow C_6H_6O_6(aq) + 2I^-(aq) + 2H^+(aq)$

(c) *Titres: 15.05; 13.96; 13.78; 13.92. Average 13.89 mL.*
$n(S_2O_3^{2-})$ *added* $= 0.0493 \times 0.01389$
$= 6.848 \times 10^{-4}$ *mol*
Ratio $S_2O_3^{2-} : I_2$ *is 2 : 1 so:*
$n(I_2)$ *in aliquot* $= ½ \times 6.848 \times 10^{-4}$
$= 3.423 \times 10^{-4}$ *mol. In 20 mL*
$\therefore$ *in 250 mL* $n(I_2) =$
$= 4.280 \times 10^{-3}$ *mol*
$n_2 = 4.280 \times 10^{-3}$ *mol*
$n_1 = 0.0521 \times 0.1 = 0.00521$ *mol*
$n(I_2)$ *reacted* $= n_1 - n_2 = 0.00521 - 0.004280$
$= 9.301 \times 10^{-4}$ *mol*
$n(C_6H_8O_6) = n(I_2) = 9.301 \times 10^{-4}$ *mol in tablet*
$Mr(C_6H_8O_6) = 176.124\ g\ mol^{-1}$
$m(C_6H_8O_6) = 9.301 \times 10^{-4} \times 176.124$
$= 0.164\ g$