

EXPLORING

CHEMISTRY

YEAR 12 - EXPERIMENTS, INVESTIGATIONS & PROBLEMS

Worked Solutions

The STAWA *Worked Solutions* have been developed through the collaboration of teachers working in Department of Education, Catholic Education WA and Association of Independent Schools of WA. Funding assistance was provided by the Department of Education.

The *Worked Solutions* are intended to support the Chemical understanding and problem solving section of the STAWA ATAR Exploring Chemistry Year 12: experiments, investigations and problems.

In an endeavour to provide the highest quality publication, the STAWA *Worked Solutions* were written and checked by different teachers. This does not guarantee that all answers are correct. Teachers are advised to work through disputed solutions with their students. If they are sure there is an error then they are asked to forward corrections to STAWA by email: admin@stawa.net

The STAWA *Worked Solutions* are a great example of teachers helping teachers for the benefit of all students.

Answers

Measurement in Chemistry

Set 1: Significant figures and unit conversion

- (a) 3 (b) 3 (c) 3 (d) 3 (e) 3
 (f) 4 (g) 6 (h) 3
- (a) 6.409×10^3 (b) 3.2×10^{-2} (c) 8.91×10^5
 (d) 5.38×10^1 (e) 6.1×10^{-6}
- (a) $8 \times 10^{-4} (\times 10^3) = 0.8 \text{ mm}$ (d) $7.03 \times 10^5 (\div 10^3) = 703 \text{ L}$
 (b) $4.5 \times 10^3 (\div 10^3) = 4.5 \text{ kg}$ (e) $0.05 \times 10^4 (\times 10^3) = 5 \times 10^5 \text{ mL}$
 (c) $9.0 \times 10^{-2} (\times 10^3) = 90 \text{ g}$ (f) $2.59 (\div 10^9) = 2.59 \times 10^{-9} \text{ m}$
- In addition or subtraction calculations the answer can have no more digits to the right of the decimal point than are contained in the measurement with the least number of digits to the right of the decimal point.

3.104

0.72

16.2

+0.002

20.026 g = 20.0 to the first decimal place Answer: 2.00×10^1

- 20 kg = $20 \times 10^3 \text{ g}$: Number of atoms = total mass \div mass per atom
 = $(20 \times 10^3) \div (3.819 \times 10^{-23})$
 = $(20 / 3.819) \times (10^{3+23})$
 = 5×10^{23} atoms

6.

	Pressure - mmHg	Pressure - atm	Pressure - Pa
(a)	760	1.00	1.01×10^5
(b)	750	9.87×10^{-1}	9.97×10^{-1}
(c)	1.56×10^3	2.05	2.07×10^5
(d)	100	1×10^{-1}	1×10^5
(e)	4.83×10^3	6.36×10^0	7.31×10^3

- In addition or subtraction calculations the answer can have no more digits to the right of the decimal point than are contained in the measurement with the least number of digits to the right of the decimal point (see qn 4)
 $0.103 + 11.45 + 0.01 + 0.001 + 68.53 = 80.094 = 80.09 \text{ g}$ (to 2nd decimal place) Answer: 8.009×10^1

Set 2: Errors

- (a) first weighing = $\pm 2 \text{ mg}$ $\therefore 0.002/12.363 \times 100 = 0.02\%$; final weighing $\pm 2 \text{ mg}$ $\therefore 0.002/0.834 \times 100 = 0.2\%$
 (b) Total error $\pm 4 \text{ mg} = \pm 4 \text{ mg} = 0.004/0.834 \times 100 = 0.5 \%$
- $153/36671 \times 100 = 0.417 \%$
- (a) 1 part in 3000 so $3000 \times 0.2 = 600 \text{ mg}$
 (b) Min Mass = $(0.2 \times 100) / 0.01 = 2000 \text{ mg}$ or 2 g
- (a) Smallest mass: $80.1 - 40.2 = 39.9 \text{ g}$ (b) $(80.3 - 40.0) \pm (0.2 + 0.2) = 40.3 \pm 0.4 \text{ g}$
- $6.8245 \div 1.13 = 6.03938$ (the answer is expressed to the least number of significant figures, which is 3) = **6.04**
- 0.0229 or 2.29×10^{-2} (the answers is expressed to the least number of significant figures, which is 3)
- (a) $1.67 \times 10^2 \text{ }^\circ\text{C}$ or $167 \text{ }^\circ\text{C}$ (b) $-2 \times 10^1 \text{ }^\circ\text{C}$ or $-20 \text{ }^\circ\text{C}$
- (a) $13.6 \times 96.485 = 1.31 \times 10^3 \text{ kJ mol}^{-1}$ (b) $24.6 \times 96.485 = 2.37 \times 10^3 \text{ kJ mol}^{-1}$
 (c) $9.32 \times 96.485 = 8.99 \times 10^2 \text{ kJ mol}^{-1}$
- $350 / 1920 \times 100 = 18\%$
- 0.24 or 2.4×10^{-1} (the answers is expressed to the least number of significant figures, which is 2)

Set 3: Random and systematic and errors

1. Random Error: b and d Systematic Error: a and c
2. No one was right. The instrument can only be read to half a graduation. The bottom of the meniscus should be read so 3.6 or 3.7 mL volume would be acceptable readings.
3. Add percentage errors: $(0.12/17)100 + (0.16/273)100 = 0.7655 = 0.77\%$
4. density = m/v
 $v = m/\text{density} = 3.0 / 2.7 = 1.111 \text{ cm}^3$
 $v = 51 \times 3 \times \text{thickness}$
thickness = $1.111 / (51 \times 3) = 0.007262 = 7.26 \times 10^{-3} \text{ cm}$
5. (a) Jenny (b) No only random errors can be eliminated by repeating an experiment
(c) Obtain new glassware and solutions
6. (a) actual error in each titre is half the smallest scale division 0.5 mL or 0.0005 L
(b) % error: $(0.5/20.9)100 = 2.39\%$.
7. parallax error – note the view of the circles around the burette
8. (a) Lyndon has random errors, Jenny has a close set of inaccurate results - systematic error
(b) Jenny has high precision and low accuracy, while Lyndon has low accuracy and low precision
(c) Jenny needs to adjust the sights or obtain new equipment. Lyndon needs coaching
9. (a) $(0.6/600)100 = 0.1\%$
(b) $(0.6/250)100 = 0.24\%$
(c) $(0.6/30)100 = 2\%$
10. (a) $(0.05/10.5)100 = 0.48\%$
(b) $(0.05/25.3)100 = 0.20\%$
(c) $(0.05/37.2)100 = 0.13\%$
11. $M(\text{NaHCO}_3) = 22.99 + 1.008 + 12.01 + 48 = 84.008$
 $n(\text{NaHCO}_3) = m/M = 2.445 / 84.008 = 0.0291 \text{ mol}$
 $c(\text{NaHCO}_3) = n/V = 0.0291 / 0.2500 = 0.1164 \text{ mol L}^{-1}$
% error (assume no error for mass) = $(0.3 / 250.0) \times 100 = \pm 0.12\%$
 $c(\text{NaHCO}_3) = 0.1164 \text{ mol L}^{-1} \pm 0.12\%$

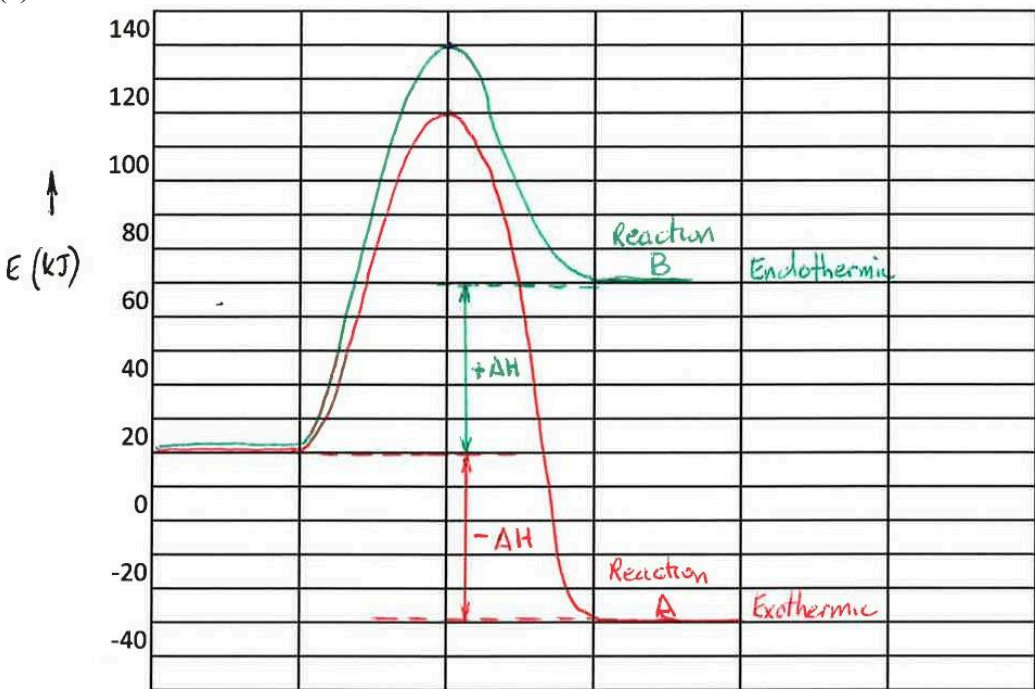
absolute error / 0.11642 = 0.12 %
absolute error = $0.12/100 \times 0.11642 = 0.00014 \text{ mol L}^{-1}$
 $c(\text{NaHCO}_3) = 0.11642 \pm 0.00014 \text{ mol L}^{-1}$
12. (a) Average titre = 22.53 mL (23.15 is outlier)
Error due to glassware = $(2 \times 0.05) \times 3 \text{ readings} = 0.3 \text{ mL}$
% error = $0.3/22.53 \times 100 = 1.33\%$
(b) Error due to range of titres = $22.60 - 22.45 = 0.15 \text{ mL}$
% error = $0.15/22.53 \times 100 = 0.67\%$
(c) % uncertainty in conical flask will be due to pipette
 $0.06/20.00 \times 100 = 0.3\%$
 $n(\text{NaHCO}_3) = 0.0446 \times 0.02000 = 8.92 \times 10^{-4} \text{ mol}$
(d) $n(\text{H}^+) = n(\text{NaHCO}_3) = 8.92 \times 10^{-4} \text{ mole}$
 $C(\text{HCl}) = 8.92 \times 10^{-4} / 0.02253 = 3.96 \times 10^{-2} \text{ mol L}^{-1}$
% uncertainty (using glassware tolerance) = $1.33 + 0.3 = 1.63\%$
Absolute uncertainty = $1.63/100 \times 3.96 \times 10^{-2} = 6.45 \times 10^{-4}$

Answers

13. (a) average titre = $(5.44 + 5.60 + 5.55)/3 = 5.53$
 Absolute Uncertainty (glassware) = $(2 \times 0.10) \times 3 = 0.60 \text{ mL}$
 % uncertainty = $0.6/5.53 \times 100 = 11\%$
- (b) average titre = $(24.50 + 24.45 + 24.30)/3 = 24.42 \text{ mL}$
 % uncertainty = $0.6/24.42 \times 100 = 2.5\%$
- (c) The smaller the average titre, the greater the effect of the tolerance of the glassware on the uncertainty. From the data above, it can be seen that diluting reduces the error significantly.

Chemical equilibrium

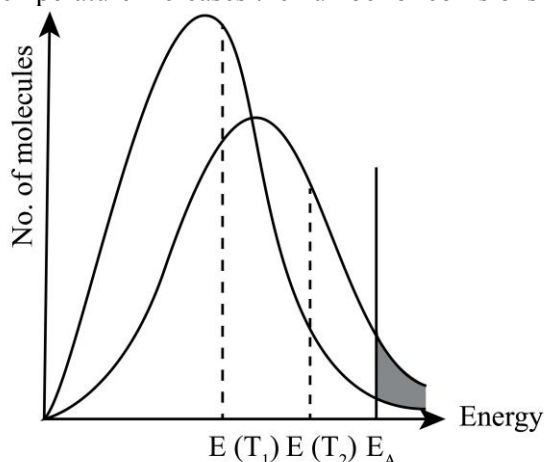
Set 4: Reaction rates and energy

- Perform the experiment on a balance and observe the rate of loss of mass
 - Capture the hydrogen by downward delivery of water and read the level of gas at regular intervals
- Ions in solution need no activation energy, have an infinite surface area while the sugar requires large activation energy and has relatively small surface area
- increased concentration - more collisions higher rate of forward reaction
 - increasing the concentration of the acid - more collisions and a higher rate of reaction
- increasing pressure decreases volume means concentration increases so the rate will increase
 - no effect as reactants are solutions
- The catalyst provides a new pathway of lower activation energy. Offering a new pathway with lower activation energy means more particles can achieve activation and the rate will increase.
- 

- The heat of reaction of an endothermic reaction is positive ($+\Delta H$), heat is absorbed from the surroundings so the reaction vessel feels cold, while the exothermic reaction releases energy to the surroundings, feels hot, expressed as a negative heat of reaction ($-\Delta H$).
- Reaction A has the lower activation energy so you would expect it (given all other factors equal) to be the faster reaction
 - The reverse of Reaction B would be faster as it has the lower activation energy, 70 kJ.

Answers

7. Increasing the temperature of a reaction increases its rate. More molecules or reacting particles have energy equal or greater than the activation energy as shown by the shaded section of the graph below. The higher temperature increases the number of collisions and the probability of a collision resulting in a reaction.



$E(T)$ = average energy at temperature T

$T_1 < T_2$

The proportion of molecules with energy equal to or greater than the activation energy, E_A (shaded areas) increases with an increase in temperature

Set 5: Equilibrium constant expressions

1. $K = \frac{[\text{H}_2\text{O}]^2}{[\text{H}_2]^2[\text{O}_2]}$	8. $K = [\text{CO}_2]$
2. $K = \frac{[\text{N}_2][\text{O}_2]}{[\text{N}_2\text{O}]^2}$	9. $K = \frac{[\text{CO}_3^{2-}][\text{NH}_4^+]}{[\text{HCO}_3^-][\text{NH}_3]}$
3. $K = \frac{[\text{CH}_3\text{OH}]}{[\text{H}_2]^2[\text{CO}_2]}$	10. $K = \frac{1}{[\text{SO}_3]}$
4. $K = \frac{[\text{Ag}^+]^2[\text{CrO}_4^{2-}]}{[\text{Ag}_2\text{CrO}_4]}$	11. $K = \frac{[\text{H}_2\text{O}][\text{CO}_2]}{[\text{C}_6\text{H}_{12}\text{O}_6]}$
5. $K = \frac{[\text{HCO}_3^-][\text{H}^+]}{[\text{CO}_2]}$	12. $K = \frac{1}{[\text{Cl}_2]}$
6. $K = \frac{[\text{SO}_4^{2-}][\text{H}_3\text{O}^+]}{[\text{HSO}_4^-]}$	13. $K = \frac{[\text{Ca}^{2+}][\text{HCO}_3^-]^2}{[\text{CO}_2]}$
7. $K = \frac{[\text{CrO}_4^{2-}]^2[\text{H}^+]^2}{[\text{Cr}_2\text{O}_7^{2-}]}$	14. $K = \frac{[\text{HCl}]^2}{[\text{H}_2\text{O}][\text{CO}_2]}$

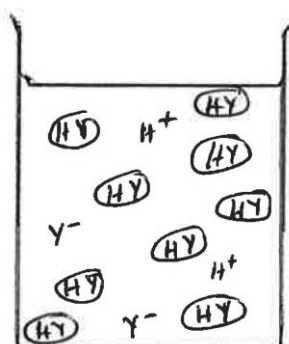
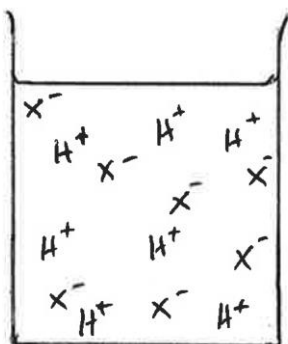
Set 6: Equilibrium systems

1. (a) $K = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3}$
 (b) (i) decrease (ii) increase (iii) increase (iv) no change
2. (a) $K = \frac{[\text{H}^+]^4[\text{OCl}^-]^2}{[\text{Cl}_2]}$
 (b) (i) increase (ii) decrease (iii) increase (iv) decrease
3. (a) (i) decrease (ii) decrease (iii) increase
 (b) (i) decrease (ii) no change (iii) increase
4. (a) (i) increase (ii) increase (iii) decrease
 (b) (i) increase (ii) decrease (iii) decrease
5. (a) (i) increase (ii) decrease (iii) no change then decrease
 (b) (i) no effect (ii) same concentration (pressure) but more CO_2 is present (iii) increase

Acids and bases

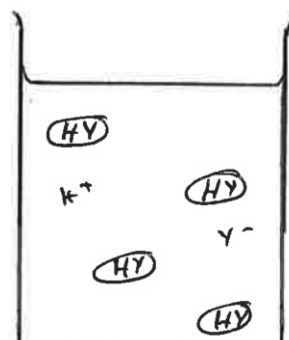
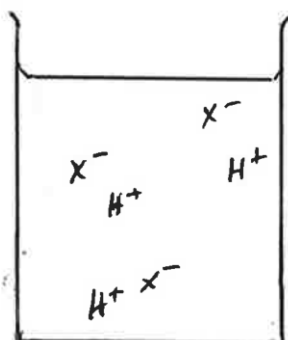
Set 8 Acids and bases

1. Conjugate acids: HF, HCO₃⁻, HClO₄, HSO₃⁻, NH₄⁺ 2. Conjugate bases: Br⁻, SO₄²⁻, HPO₄²⁻, S²⁻, NO₃⁻, OH⁻
3. (a) H₂SO₄(aq) + H₂O(l) → H₃O⁺(aq) + SO₄²⁻(aq) (c) KOH(aq) → K⁺(aq) + OH⁻(aq)
 (b) H₂S(aq) + H₂O(l) ⇌ H₃O⁺(aq) + HS⁻(aq) (d) N₂H₄(aq) + H₂O(l) ⇌ H⁺(aq) + HS⁻(aq)
4. A strong acid completely ionises in solution, while a weak acid only partially ionises in solution. Acid concentration refers to the amount of acid dissolved. A concentrated solution contains a high proportion of acid, while a dilute acid solution is mainly water with a very small proportion of acid.
- (a) Concentrated solution of a strong acid (HX) (b) Concentrated solution of a weak acid (HY)



(c) Dilute solution of a strong acid (HX)

(d) Dilute solution of a weak acid (HY)



5. I. conjugate acid–base pairs II. Reaction favours the:
- | | |
|--|------------------|
| a. HF (aq) + H ₂ O (l) ⇌ F ⁻ (aq) + H ₃ O ⁺ (aq)
acid base conjugate base conjugate acid | forward reaction |
| b. HSO ₄ ⁻ (aq) + NH ₃ (aq) ⇌ SO ₄ ²⁻ (aq) + NH ₄ ⁺ (aq)
acid base conjugate base conjugate acid | forward reaction |
| c. H ₂ CO ₃ (aq) + F ⁻ (aq) ⇌ HCO ₃ ⁻ (aq) + HF(aq)
acid base conjugate base conjugate acid | reverse reaction |
| d. H ₂ PO ₄ ⁻ (aq) + H ₂ O (l) ⇌ H ₃ O ⁺ (aq) + HPO ₄ ²⁻ (aq)
acid base conjugate acid conjugate base | forward reaction |

Set 9: Acid and base strength

1. Concentration is a measure of the proportion of solute in a solution. Strength refers to the degree of ion formation that occurs when an acid or base is dissolved in water. For example, hydrogen chloride completely ionises in water and is classified as a strong acid: HCl(aq) → H⁺(aq) + Cl⁻(aq)
- When the very soluble hydrogen fluoride dissolves in water there is little ionisation and it is classified as a weak acid: HF(aq) ⇌ H⁺(aq) + F⁻(aq)

Answers

2. (a) HCl , HNO_3 , H_2SO_4 , HBr , HI , HClO_4 ,
 (b) CH_3COOH , H_2S , HF , H_3PO_4 , $\text{H}_2\text{C}_2\text{O}_4$, HSO_4^- , or any organic acid.
 (c) NaOH , KOH , $\text{Ba}(\text{OH})_2$, $\text{Ca}(\text{OH})_2$, or any metal hydroxide or oxide.
 (d) NH_3 , CO_3^{2-} , CH_3NH_2 or any organic amine.
3. (a) Concentrated and weak (b) Dilute and strong (c) Concentrated and strong (d) Dilute and weak
4. (i) (a) $\text{HBr}(\text{g}) \rightarrow \text{H}^+(\text{aq}) + \text{Br}^-(\text{aq})$ (b) ionisation
 (c) HBr , OH^- , Br^- , H_3O^+ , H_2O
- (ii) (a) $\text{CH}_3\text{COOH}(\text{l}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{CH}_3\text{COO}^-(\text{aq})$ (b) ionisation
 (c) OH^- , CH_3COO^- , H_3O^+ , CH_3COOH , H_2O
- (iii) (a) $\text{H}_2\text{SO}_4(\text{l}) \rightarrow \text{H}^+(\text{aq}) + \text{HSO}_4^-(\text{aq})$ and $\text{HSO}_4^-(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq})$
 (b) ionisation (c) H_2SO_4 , OH^- , SO_4^{2-} , HSO_4^- , H_3O^+ , H_2O
- (iv) (a) $\text{NH}_3(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq})$ (b) ionisation
 (c) H_3O^+ or H^+ , NH_4^+ , OH^- , NH_3 , H_2O
- (v) (a) $\text{Ba}(\text{OH})_2(\text{aq}) \rightarrow \text{Ba}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq})$ (b) dissociation
 (c) $\text{Ba}(\text{OH})_2$, H_3O^+ , Ba^{2+} , OH^- , H_2O
5. Stronger acid is HClO_4 and the weaker base is ClO_4^-
6. (a) $\text{H}_2\text{S}(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{HS}^-(\text{aq})$ and $\text{HS}^-(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{S}^{2-}(\text{aq})$
 (b) Strongest acid is H_3O^+ and the strongest base is S^{2-}
7. (a) $\text{H}_3\text{PO}_4(\text{l}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{H}_2\text{PO}_4^-(\text{aq}) > \text{H}_2\text{PO}_4^-(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HPO}_4^{2-}(\text{aq}) > \text{HPO}_4^{2-}(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{PO}_4^{3-}(\text{aq})$
 (b) H_2O , H_3PO_4 , H_3O^+ , H_2PO_4^- , HPO_4^{2-} , PO_4^{3-} , OH^-
8. 99% sulfuric acid consists mostly of H_2SO_4 molecules, as there is little water to allow ionisation, so there are very few hydrogen ions to react with the iron. 2 mol L^{-1} sulfuric acid is a strong acid; there is full ionisation for the release of one hydrogen ion represented by the equation: $\text{H}_2\text{SO}_4(\text{l}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{HSO}_4^-(\text{aq})$
 There is therefore a high concentration of hydrogen ions which is the species that reacts with the iron in a reaction represented by the equation $2\text{H}^+(\text{aq}) + \text{Fe}(\text{s}) \rightarrow \text{Fe}^{2+}(\text{aq}) + \text{H}_2(\text{g})$
 Steel wool has a very high surface area and so there are more collisions and a higher rate of reaction.
9. For effective washing, large numbers of OH^- ions are required in the washing powder. To supply these substantial amounts of sodium hydroxide or sodium carbonate need to be present. The sodium hydroxide, being a strong base will produce a high concentration of OH^- ions which can be detrimental to fabrics. It is also dangerous to use, as concentrated OH^- solutions are corrosive to skin. Sodium carbonate, however, is a weak base that produces relatively low concentrations of OH^- ions but as these are consumed, more are produced until all of the carbonate ions are used up. The production of the OH^- ions from the carbonate ions is illustrated by the equation: $\text{CO}_3^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{HCO}_3^-(\text{aq}) + \text{OH}^-(\text{aq})$
10. For this use the hydrogen ion concentration produced in the solution must be very low but there must be a process that replaces the hydrogen ions that are used up. It must therefore be a weak acid. As hydrochloric acid is a strong acid the concentration of hydrogen ions, even in dilute solutions, is relatively high and would damage human skin particularly in sensitive areas such as eyes and areas where fungal infections are likely to occur.

Set 10 : Hydrolysis

1. (a) neutral (b) basic (c) basic (d) acidic (e) basic
2. (b) $\text{PO}_4^{3-}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{HPO}_4^{2-}(\text{aq}) + \text{OH}^-(\text{aq})$
 (c) $\text{HCO}_3^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_2\text{CO}_3(\text{aq}) + \text{OH}^-(\text{aq})$
 (d) $\text{NH}_4^+(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_3(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$
 (e) $\text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{CH}_3\text{COOH}(\text{aq}) + \text{OH}^-(\text{aq})$

Answers

3. (a) Ammonium nitrate, calcium hydrogenphosphate, potassium sulfate, and ammonium chloride.
 (b) The salts contain either an anion of a weak acid or the cation of a weak base.
 (c) Ammonium nitrate (\downarrow pH) $\text{NH}_4^+(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{NH}_3(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$
 calcium hydrogenphosphate (\uparrow pH) $\text{HPO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{H}_2\text{PO}_4^-(\text{aq}) + \text{OH}^-(\text{aq})$
 and $\text{H}_2\text{PO}_4^-(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{H}_3\text{PO}_4(\text{aq}) + \text{OH}^-(\text{aq})$
 potassium sulfate (\downarrow pH) $\text{SO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{HSO}_4^-(\text{aq}) + \text{OH}^-(\text{aq})$
 ammonium chloride (\downarrow pH) $\text{NH}_4^+(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{NH}_3(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$
 (d) These salts contain only ions derived from strong acids and strong bases so they do not react with water to produce the strong acid or strong base.
4. $\text{Ca}(\text{H}_2\text{PO}_4)_2(\text{s}) \rightleftharpoons 2\text{H}_2\text{PO}_4^-(\text{aq}) + \text{Ca}^{2+}(\text{aq})$ and $\text{H}_2\text{PO}_4^-(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{HPO}_4^{2-}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$
5. (a) Yes, it becomes basic.
 (b) $\text{Na}_2\text{CO}_3(\text{aq}) \rightarrow 2\text{Na}^+(\text{aq}) + \text{CO}_3^{2-}(\text{aq})$ and $\text{CO}_3^{2-}(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{HCO}_3^-(\text{aq}) + \text{OH}^-(\text{aq})$
6. (a) $\text{OH}^-(\text{aq}) + \text{CH}_3\text{COOH}(\text{aq}) \rightleftharpoons \text{H}_2\text{O}(\ell) + \text{CH}_3\text{COO}^-(\text{aq})$ (b) basic, $\text{pH} > 7$.
 (c) $\text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{CH}_3\text{COOH}(\text{aq}) + \text{OH}^-(\text{aq})$
7. Yes it becomes basic as F^- is the anion of a weak acid: $\text{F}^-(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{HF}(\text{aq}) + \text{OH}^-(\text{aq})$
8. The pH of a solution of ammonium ethanoate depends on the relative strength of the weak base ammonia and the weak acid ethanoic acid. The hydrolysis process is represented by the equations:
 $\text{NH}_4^+(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{NH}_3(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$ and $\text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{CH}_3\text{COOH}(\text{aq}) + \text{OH}^-(\text{aq})$
 Their ionisation constants are both close to 1.8×10^{-5} so the solution will be neutral.

Set 11: Water equilibrium

1. $\text{H}_2\text{O}(\ell) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{OH}^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$
2. (a) $[\text{OH}^-] = 1.00 \times 10^{-14} / [\text{H}^+] = 6.76 \times 10^{-8} \text{ mol L}^{-1}$ (b) Acidic
3. $[\text{H}^+] = 1.00 \times 10^{-14} / [\text{OH}^-] = 6.33 \times 10^{-9} \text{ mol L}^{-1}$
4. (a) $[\text{H}^+] = 1.00 \times 10^{-14} / [\text{OH}^-] = 6.45 \times 10^{-11} \text{ mol L}^{-1}$
 (b) $[\text{OH}^-] = 2 \times [\text{Ba}(\text{OH})_2]$; $[\text{H}^+] = 1.00 \times 10^{-14} / [\text{OH}^-] = 1.00 \times 10^{-14} / 7.80 \times 10^{-2} = 1.28 \times 10^{-13} \text{ mol L}^{-1}$
5. (a) $[\text{OH}^-] = 1.00 \times 10^{-14} / [\text{H}^+] = 9.62 \times 10^{-14} \text{ mol L}^{-1}$
 (b) $\text{H}_2\text{SO}_4(\ell) \rightarrow \text{H}^+(\text{aq}) + \text{HSO}_4^-(\text{aq})$ and $\text{HSO}_4^-(\text{aq}) \rightarrow 0.9\text{HSO}_4^-(\text{aq}) + 0.1\text{H}^+(\text{aq}) + 0.1\text{SO}_4^{2-}(\text{aq})$
 Overall $\text{H}_2\text{SO}_4(\ell) \rightarrow 0.9\text{HSO}_4^-(\text{aq}) + 1.1\text{H}^+(\text{aq}) + 0.1\text{SO}_4^{2-}(\text{aq})$
 $[\text{H}^+] = 1.1$ $[\text{H}_2\text{SO}_4] = 1.1 \times 0.125 = 0.1375 \text{ mol L}^{-1}$ $[\text{OH}^-] = 7.27 \times 10^{-14} \text{ mol L}^{-1}$
6. (a) Ionisation of water is endothermic: $\text{heat} + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{H}^+(\text{aq}) + \text{OH}^-(\text{aq})$ a change in temperature will change the proportion of reactants and products and so change the equilibrium constant.
 (b) K value decreases. A decreased in temperature causes the equilibrium position to move to restore some of the heat removed. H^+ and OH^- combine to produce water and heat, concentration become smaller.
 (c) If temperature is increased a greater concentration of hydrogen ions will result.
 (d) As the temperature is increased the rate of both the forward and reverse reactions will increase, but the endothermic forward reaction increases more than reverse reaction so hydrogen ion concentration increases.
7. (a) $10^{-14} / [\text{H}^+] = [\text{OH}^-] = 10^{-14} / 1.55 \times 10^{-5} = 6.45 \times 10^{-10} \text{ mol L}^{-1} \text{ OH}^-$
 (b) Some release of SO_2 from the smelter with elevated levels of CO_2 dissolving in the rainwater.
 (c) $\text{SO}_2(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{HSO}_3^-(\text{aq}) + \text{H}^+(\text{aq})$ and $\text{CO}_2(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{HCO}_3^-(\text{aq}) + \text{H}^+(\text{aq})$
8. As volumes were equal, the average $[\text{H}^+] = (1.6 \times 10^{-4} + 1.3 \times 10^{-6}) / 2 = 8.065 \times 10^{-5} \text{ mol L}^{-1}$
 $[\text{H}^+] = 8.07 \times 10^{-5} \text{ mol L}^{-1}$ As $10^{-14} / [\text{H}^+] = [\text{OH}^-] = 10^{-14} / 8.07 \times 10^{-5} = 1.24 \times 10^{-10} \text{ mol L}^{-1}$

Answers

9. (a) Stomach Acid : $n = c \times v = 1.5 \times 2.5 \times 10^{-4} = 3.75 \times 10^{-4} \text{ mol H}^+$
 Al_2O_3 : $n = m/M = 5 \times 10^{-3} / (26.98 + 3(17.00)) = 6.412 \times 10^{-5} \text{ mol Al(OH)}_3 \therefore$ there are $1.93 \times 10^{-4} \text{ mol OH}^-$ available
 Mg(OH)_2 : $n = m/M = 5 \times 10^{-3} / (24.31 + 2(17.00)) = 8.575 \times 10^{-5} \text{ mol Mg(OH)}_2 \therefore$ there are $1.715 \times 10^{-4} \text{ mol OH}^-$ available
 Total $\text{OH}^- = 3.645 \times 10^{-4} \text{ mol OH}^-$ available
 The acid is INXS by $3.75 \times 10^{-4} - 3.645 \times 10^{-4} = 1.05 \times 10^{-5} \text{ mol}$
 $c = n/v = 1.05 \times 10^{-5} / 1.5 = 7.00 \times 10^{-6} \quad [\text{OH}^-] = 1.43 \times 10^{-9} \text{ mol L}^{-1}$
- (b) Excess Al(OH)_3 and Mg(OH)_2 would remain undissolved (both insoluble in water) and the concentration of both hydrogen and hydroxide ions would therefore be $1.00 \times 10^{-7} \text{ mol L}^{-1}$.
10. (a) $V(\text{Mg(OH)}_2) = 4.86 \text{ mL}$
 (b) $[\text{H}^+] = 8.34 \times 10^{-3} \text{ mol L}^{-1} \quad [\text{OH}^-] = 1.20 \times 10^{-12} \text{ mol L}^{-1}$

Set 12: Indicators and their use

1. (a) An organic acid or base
 (b) The acid must be distinctly different in colour from its conjugate base:
 e.g.: $\text{H(Litmus)}(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + (\text{Litmus})^-(\text{aq})$
Red Blue
2. (a) $\text{H(Indicator)}(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + (\text{indicator})^-(\text{aq})$
 (b) Addition of an acid increases $[\text{H}^+]$, causes more H(Indicator) to be produced and a reduction in the concentration of $(\text{Indicator})^-$. The colour changes from the $(\text{Indicator})^-$ colour to the H(Indicator) colour.
 (c) Addition of a base reduces $[\text{H}^+]$ as H^+ reacts with OH^- to produce water. This causes the production of more $(\text{Indicator})^-$ and less H(Indicator) . The colour changes from H(Indicator) colour to $(\text{Indicator})^-$ colour.
 (d) *Addition of Acid:* increase in the rate of the reaction producing H(Indicator) with no immediate change to the reaction producing $(\text{Indicator})^-$ hence a colour change from $(\text{Indicator})^-$ colour to H(Indicator) colour.
Addition of Base: a reduction in $[\text{H}^+]$ causes a reduction in the rate of the reaction producing H(Indicator) with no immediate change in the rate of the reaction producing $(\text{Indicator})^-$ hence a colour change from H(Indicator) colour to $(\text{Indicator})^-$ colour.

3.

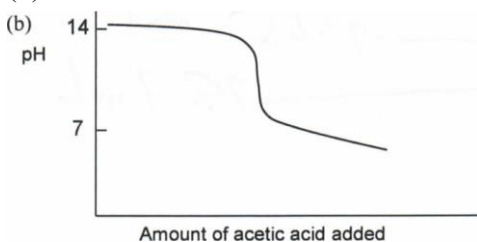
(a)	Phenolphthalein	Alizarin Yellow	Indigo Carmine
(b)	<pH=8.3 Colourless)	<pH = 10.1 (Yellow)	<pH = 11.4 (Blue)
	>pH = 10 (Pink)	>pH = 12.0 (Red)	>pH = 13.0 (Yellow)
(c)	8.3 to 10	10.1 to 12.0	11.4 to 13.0

4.

(a)	Methyl red	Methyl orange	Bromophenol blue	Methyl violet
(b)	<pH = 4.4 (Red) >pH = 6.2 (Yellow)	<pH = 3.1 (Red) >pH = 4.4 (Yellow)	<pH = 3.0 (Yellow) >pH = 4.6 (blue)	<pH = 0 (Yellow) >pH = 1.6 (Violet)
(c)	4.4 to 6.2	3.1 to 4.4	3.0 to 4.6	0 to 1.6

5. (a) H_2O , Na^+ , CH_3COO^- , OH^- , CH_3COOH , H^+

(b)



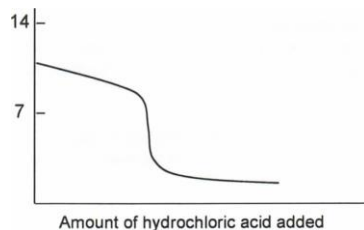
(c) The solution is basic: $\text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{CH}_3\text{COOH}(\text{aq}) + \text{OH}^-(\text{aq})$

(d) Phenolphthalein. The end point (colour changes) must occur at the equivalence point. Equivalence point is basic use indicator that changes colour within pH 7 and 11. Phenolphthalein changes in pH range 8.3 to 10.

Answers

6. (a) H_2O , Cl^- , NH_4^+ , H_3O^+ , NH_3 , OH^-

(b)

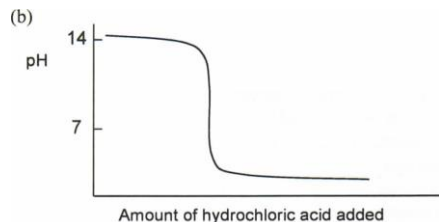


(c) The solution is acidic: $\text{NH}_4^+(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_3(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$

(d) Methyl orange, methyl red or bromothymol blue. Acid end point use indicator that changes colour at a pH between about 3 and 7.

7. (a) H_2O , $\text{Ca}^{2+} / \text{Cl}^-$, OH^- / H^+

(b)



(c) The solution is neutral. Calcium ion and chloride ion do not undergo hydrolysis.

(d) End point pH = 7: Indicator that changes colour in the range of pH = about 3 to 11.

8. (a) Phenolphthalein (b) More acid will be used (c) Concentration measured lower than it actually is

Set 13: The pH scale

- (a) $[\text{H}^+] = [\text{HCl}] = 0.100 \text{ mol L}^{-1}$ $[\text{OH}^-] = 1.00 \times 10^{-13} \text{ mol L}^{-1}$; pH = 1.00

(b) $[\text{H}^+] = [\text{HNO}_3] = 0.00500 \text{ mol L}^{-1}$ $[\text{OH}^-] = 2.00 \times 10^{-12} \text{ mol L}^{-1}$; pH = 2.30

(c) $[\text{OH}^-] = [\text{NaOH}] = 0.0100 \text{ mol L}^{-1}$ $[\text{H}^+] = 1.00 \times 10^{-12} \text{ mol L}^{-1}$; pH = 12.0

(d) $[\text{H}^+] = [\text{HCl}] = 2.00 \text{ mol L}^{-1}$ $[\text{OH}^-] = 5.00 \times 10^{-15} \text{ mol L}^{-1}$; pH = 0.300

(e) $[\text{H}^+] = [\text{OH}^-] = 1.00 \times 10^{-14} \text{ mol L}^{-1}$ and the pH = 7.00. Neutral as solutions of Na^+ ions and Cl^- ions do not hydrolyse in water.
- (a) $[\text{H}^+] = 1.00 \times 10^{-3} \text{ mol L}^{-1}$ $[\text{OH}^-] = 1.00 \times 10^{-11} \text{ mol L}^{-1}$

(b) $[\text{H}^+] = 1.00 \times 10^{-11} \text{ mol L}^{-1}$ $[\text{OH}^-] = 1.00 \times 10^{-3} \text{ mol L}^{-1}$

(c) $[\text{H}^+] = 10.0 \text{ mol L}^{-1}$ $[\text{OH}^-] = 1.00 \times 10^{-15} \text{ mol L}^{-1}$

(d) $[\text{H}^+] = 2.75 \times 10^{-5} \text{ mol L}^{-1}$ $[\text{OH}^-] = 3.63 \times 10^{-10} \text{ mol L}^{-1}$

(e) $[\text{H}^+] = 2.51 \times 10^{-8} \text{ mol L}^{-1}$ $[\text{OH}^-] = 3.98 \times 10^{-7} \text{ mol L}^{-1}$
- Concentration changed by a factor of 1000
- Depleted Solution: pH = 2 $\therefore [\text{H}^+] = 10^{-2}$ so $n = c \times v = 0.01 \times 2 = 0.02 \text{ mol H}^+$
 Added acid : $n = c \times v = 3.00 \times 3.00 = 9.00 \text{ mol H}^+$
 Total acid = 9.02 mol New $c = n/v = 9.02 / 5 = [\text{H}^+] = 1.80 \text{ mol L}^{-1}$
- pH 5 = $10^{-5} \text{ mol L}^{-1} = 0.00001 \text{ mol L}^{-1}$ pH 3.6 = $10^{-3.6} \text{ mol L}^{-1} = 2.52 \times 10^{-4} \text{ mol L}^{-1}$
 $c_1v_1 = c_2v_2 = 10^{-5} \times X = 0.025 \times 2.52 \times 10^{-4} = 630 \text{ mL}$
 Water required = 630 - 25.0 = 605 mL
- pH 12 \therefore pOH = 2 so $[\text{OH}^-] = 0.01 \text{ mol L}^{-1}$ pH 11.7 \therefore pOH = 2.3 so $[\text{OH}^-] = 10^{-2.3} = 0.0050 \text{ mol L}^{-1}$
 \therefore he needs to add 0.01 - 0.0050 = 0.005 mol/L
 He has only 100mL so needs to add 0.0005 mol NaOH
 $m(\text{NaOH})_{\text{to be added}} = nM = 0.0005 \times 39.998 = 0.0200 \text{ g} = 20.0 \text{ mg}$

Answers

7. (a) Drain : $n = c \times v = 0.236 \times 0.200 = 0.0472 \text{ mol}$
 Runoff : $n = c \times v = 0.156 \times 0.300 = 0.0468 \text{ mol}$
 New $c = n/v = (0.0472 + 0.0468) / (0.2 + 0.3) = 0.188 \text{ mol L}^{-1} \text{ OH}^-$
 $\therefore \text{pOH} = 0.726 \therefore \text{pH} = 14 - 0.726 = 13.3$
 (b) $V(\text{HCl}) = n(\text{H}^+) / c = 0.094 / 1 = 0.094 \text{ L} = 94 \text{ mL}$ per 500 mL $\therefore 188 \text{ mL}$ per litre
8. $\text{pH } 5.5 \therefore [\text{H}^+] = 10^{-5.5} = 3.162 \times 10^{-6} \text{ mol L}^{-1}$
 $n = c \times v = 3.162 \times 10^{-6} \times 15000 = 4.743 \times 10^{-2} \text{ mol H}^+$
 $\text{NaOH} : 10\text{g} \therefore n = m/M = 10/39.99 = 0.25 \text{ mol of OH}^-$
 Result : $0.2026 \text{ mol NaOH INXS} \therefore c = n/v = 0.2026/15000 = 1.351 \times 10^{-5} \text{ mol L}^{-1} \text{ OH}^-$
 \therefore the $\text{pOH} = 4.87 \therefore \text{pH} = 14 - 4.87 = 9.13$
9. $\text{pH } 7.20 \therefore [\text{H}^+] = 10^{-7.2} = 1.584 \times 10^{-8} \text{ mol L}^{-1} \text{ H}^+$
 $n = c \times v = 1.584 \times 10^{-8} \times 2.0 \times 10^6 = 0.03168 \text{ mol H}^+$
 $\text{pH } 7.8 \therefore [\text{H}^+] = 10^{-7.8} = 6.3095 \times 10^{-8} \text{ mol L}^{-1} \text{ H}^+$
 $n = c \times v = 6.3095 \times 10^{-8} \times 2.0 \times 10^6 = 0.12619 \text{ mol H}^+$
 Needs to increase mol H^+ by $0.12619 - 0.03168 = 0.09451 \text{ mol}$
 $V(\text{HCl}) = n(\text{H}^+_{\text{required}}) / c = 0.09451/12.0 = 7.87 \text{ mL}$
10. (a) $\text{pH } 6.75 \therefore [\text{H}^+] = 10^{-6.75} = 1.778 \times 10^{-7} \text{ mol L}^{-1} \text{ H}^+$
 $\text{pH } 5.1 \therefore [\text{H}^+] = 10^{-5.1} = 7.943 \times 10^{-6} \text{ mol L}^{-1} \text{ H}^+$
 Average = $4.0605 \times 10^{-6} \text{ mol L}^{-1} \text{ H}^+$
 $\text{pH} = -\log_{10}[\text{H}^+] = -\log_{10}(4.059 \times 10^{-6}) = 5.39$
- (b) $\text{pH } 6.75 \therefore [\text{H}^+] = 10^{-6.75} = 1.778 \times 10^{-7} \text{ mol L}^{-1} \text{ H}^+$
 $\text{pH } 8.00 \therefore \text{pOH} = 6 \therefore [\text{OH}^-] = 10^{-6} = 1 \times 10^{-6} \text{ mol L}^{-1} \text{ OH}^-$
 Mix 1 L of each
 $\text{OH}^- \text{ INXS by} : 1 \times 10^{-6} - 1.68 \times 10^{-7} = 8.22 \times 10^{-7} \text{ mol OH}^-$
 $c = n/v = 8.22 \times 10^{-7} / 2 = 4.11 \times 10^{-7} \text{ mol L}^{-1} \text{ OH}^-$
 $\text{pOH} = -\log_{10}[\text{OH}^-] = -\log_{10}(4.11 \times 10^{-7}) = 6.39$
 $\therefore \text{pH} = 14 - 6.39 = 7.61$

Set 14: Buffers

1. Buffer solutions resist a change in pH even with the addition of substantial amounts of hydrogen or hydroxide ions. Many specific reactions that occur in biological systems occur only at specific pH values. Some reactions produce or use up hydrogen ions in these solutions. Buffers prevent large changes in the pH of solutions such as - blood, cell contents and lymph system allowing vital reactions to continue.
2. $\text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\ell)$ $\text{NH}_3(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{NH}_4^+(\text{aq})$
 Thus a buffer can accept or donate a proton to approximately maintain pH
3. Buffer solutions can be produced that have specific and known pH value. The fixed pH values are used as standards to calibrate the meters.
4. (a) Hypochlorite ions added to pool water as sodium hypochlorite solution or calcium hypochlorite solid to kill micro organisms. Weak acid hypochlorous acid forms: $\text{OCl}^-(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{HOCl}(\text{aq}) + \text{OH}^-(\text{aq})$
 The buffer uses up some of these OH^- ions stopping the pool water becoming alkaline too quickly.
 (b) $\text{OH}^-(\text{aq}) + \text{HCO}_3^-(\text{aq}) \rightleftharpoons \text{H}_2\text{O}(\ell) + \text{CO}_3^{2-}(\text{aq})$ and $\text{HCO}_3^-(\text{aq}) \rightleftharpoons \text{CO}_3^{2-}(\text{aq}) + \text{H}^+(\text{aq})$: H^+ reacts with the OH^- .
 Both processes use up OH^- ions.
5. (a) H_2O and HCO_3^- ion (b) $\text{CO}_2(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{HCO}_3^-(\text{aq}) + \text{H}^+(\text{aq})$
 H^+ ion is used up by reacting with the HCO_3^- and OH^- ions is used up by reacting with CO_2 directly,
 $\text{OH}^-(\text{aq}) + \text{CO}_2(\text{aq}) \rightleftharpoons \text{HCO}_3^-(\text{aq})$ or with H^+ ions, results in more H^+ ions. $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightleftharpoons \text{H}_2\text{O}(\ell)$
6. Method 1: Add an equal volume of 1 mol L^{-1} sodium ethanoate solution
 Method 2: Add an equal volume of a 0.5 mol L^{-1} solution of sodium hydroxide. This would react with half the acetic acid to produce acetate ion as in the equation: $\text{CH}_3\text{COOH}(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_2\text{O}(\ell)$

Answers

7. Method 1 Make a solution in water of the sodium citrate mixed with an equal number of moles of citric acid.
 Method 2 Make a solution in water of the sodium citrate add 1½ times number of moles of hydrochloric acid.
 This reacts with half the citrate ion: $\text{C}_6\text{H}_5\text{O}_7^{3-}(\text{aq}) + 3\text{H}^+(\text{aq}) \rightleftharpoons \text{H}_3\text{C}_6\text{H}_5\text{O}_7(\text{aq})$
8. A change in temperature changes the equilibrium concentration of the species in equilibrium and as one of the species is always either H^+ or OH^- ions, changing their concentrations changes the pH.

Set 15: Acid-base titrations 1

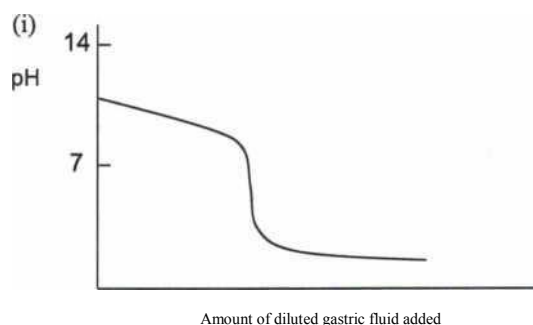
1. (a) $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\ell)$
 $n(\text{H}^+) = cV = (2.00 \times 0.100) = 0.200 \text{ mol}$
 $n(\text{OH}^-) = n(\text{NaOH}) = n(\text{HCl}) = n(\text{H}^+)$
 $V(\text{NaOH}) = n/c = 0.200 / 0.500 = 0.400 \text{ L or } 400 \text{ mL}$ $V = 0.400 \text{ L}$
- (b) $\text{CH}_3\text{COOH}(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_2\text{O}(\ell)$
 $n(\text{CH}_3\text{COOH}) = cV = (1.50 \times 0.150) = 0.225 \text{ mol}$
 $n(\text{OH}^-) = n(\text{NaOH}) = n(\text{CH}_3\text{COOH})$
 $V(\text{NaOH}) = n/c = 0.225 / 0.500 = 0.450 \text{ L or } 450 \text{ mL}$ $V = 0.450 \text{ L}$
- (c) $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\ell)$
 $n(\text{H}^+) = 2n(\text{H}_2\text{SO}_4) = cV = 2(0.250 \times 0.020) = 0.0100 \text{ mol}$
 $n(\text{OH}^-) = n(\text{NaOH}) = n(\text{H}^+)$
 $V(\text{NaOH}) = n/c = 0.0100 / 0.500 = 0.0200 \text{ L or } 20.0 \text{ mL}$ $V = 0.0200 \text{ L}$
- (d) $\text{H}_3\text{PO}_4(\text{aq}) + 3\text{OH}^-(\text{aq}) \rightarrow \text{PO}_4^{3-}(\text{aq}) + 3\text{H}_2\text{O}(\ell)$
 $n(\text{H}^+) = 3n(\text{H}_3\text{PO}_4) = cV = 3(0.800 \times 0.0750) = 0.180 \text{ mol}$
 $n(\text{OH}^-) = n(\text{NaOH}) = n(\text{H}^+)$
 $V(\text{NaOH}) = n/c = 0.180 / 0.500 = 0.360 \text{ L or } 360 \text{ mL}$ $V = 0.360 \text{ L}$
2. (a) $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\ell)$
 $n(\text{OH}^-) = n(\text{NaOH}) = cV = (0.600 \times 0.200) = 0.120 \text{ mol}$
 $n(\text{OH}^-) = n(\text{H}^+)$
 $n(\text{H}_2\text{SO}_4) = \frac{1}{2} n(\text{H}^+) = 0.0600 \text{ mol}$
 $V(\text{H}_2\text{SO}_4) = n/c = 0.0600 / 0.200 = 0.300 \text{ L or } 300 \text{ mL}$ $V = 0.300 \text{ L}$
- (b) $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\ell)$
 $n(\text{H}_2\text{SO}_4) = n(\text{Ba}(\text{OH})_2) = cV = (0.100 \times 0.0500) = 0.00500 \text{ mol}$
 $V(\text{H}_2\text{SO}_4) = n/c = 0.00500 / 0.200 = 0.0250 \text{ L or } 25.0 \text{ mL}$ $V = 0.0250 \text{ L}$
3. $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\ell)$
 $n(\text{H}^+) = cV = (0.105 \times 0.0211) = 0.00221 \text{ mol}$
 $n(\text{OH}^-) = n(\text{KOH}) = n(\text{H}^+)$
 $c(\text{KOH}) = n/V = 0.00221 / 0.0250 = 0.0886 \text{ mol L}^{-1}$
 $8.86 \times 10^{-2} \text{ mol L}^{-1}$
4. $\text{H}_2\text{SO}_4(\text{aq}) + 2\text{NaOH}(\text{aq}) \rightarrow \text{Na}_2\text{SO}_4(\text{aq}) + 2\text{H}_2\text{O}(\ell)$
 $n(\text{H}_2\text{SO}_4) = \frac{1}{2} n(\text{NaOH}) = \frac{1}{2} (cV) = \frac{1}{2} (2.00 \times 0.0222) = 0.0222 \text{ mol}$
 $c(\text{H}_2\text{SO}_4) = n/V = 0.0222 / 0.00500 = 4.44 \text{ mol L}^{-1}$
5. $\text{Na}_2\text{CO}_3(\text{aq}) + 2\text{HNO}_3(\text{aq}) \rightarrow 2\text{NaNO}_3(\text{aq}) + \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\ell)$
 $n(\text{HNO}_3) = cV = (1.00 \times 0.00350) = 0.00350 \text{ mol}$
 $n(\text{Na}_2\text{CO}_3) = \frac{1}{2} n(\text{HNO}_3) = 0.00175 \text{ mol}$
 $c(\text{Na}_2\text{CO}_3) = n/V = 0.00175 / 0.0250 = 0.0700 \text{ mol L}^{-1}$
 $7.00 \times 10^{-2} \text{ mol L}^{-1}$
6. $\text{Mg}(\text{OH})_2 + 2\text{HCl} \rightarrow \text{MgCl}_2 + 2\text{H}_2\text{O}$
 $M(\text{Mg}(\text{OH})_2) = 24.31 + 2(16 + 1.008) = 58.326$
 $n(\text{Mg}(\text{OH})_2) = m/M = 0.450 / 58.326 = 0.00771 \text{ mol}$
 $n(\text{HCl}) \text{ reacting} = 2n(\text{Mg}(\text{OH})_2) = 0.0153 \text{ mol}$
 $V(\text{HCl}) \text{ reacting} = n/c = 0.0153 / 0.150 = 0.103 \text{ L}$
 $V(\text{HCl}) \text{ reacting} = 0.103 \text{ L}$

Answers

7. $\text{CaO} + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O}$
 $n(\text{HCl}) = cV = (1.50 \times 0.250) = 0.375 \text{ mol}$
 $n(\text{CaO}) = \frac{1}{2} n(\text{HCl}) = \frac{1}{2} (0.375) = 0.1875 \text{ mol}$
 $m(\text{CaO}) = nM = 0.1875 \times (40.08 + 16.00) = 10.5 \text{ g}$
 $m(\text{CaO}) = 10.5 \text{ g}$
8. $2\text{NaHCO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + 2\text{CO}_2 + 2\text{H}_2\text{O}$
 $m = 600 \text{ g}$ $m? V?$
 $M(\text{NaHCO}_3) = 22.99 + 1.008 + 12.01 + 48 = 84.008$
 $M(\text{H}_2\text{SO}_4) = 2(1.008) + 32.07 + 4(16.00) = 98.086$
 (a) $n(\text{NaHCO}_3) = m/M = 600 / 84.008 = 7.142 \text{ mol}$
 $n(\text{H}_2\text{SO}_4) = \frac{1}{2} n(\text{NaHCO}_3) = 3.571 \text{ mol}$
 $m(\text{H}_2\text{SO}_4) = nM = 3.571 \times 98.086 = 350 \text{ g}$
 (b) $V(\text{H}_2\text{SO}_4) = n/c = 3.571 / 12.0 = 0.297 \text{ L (297 mL)}$
9. (a) i) 0.107 mol L^{-1} (ii) 3.89 g L^{-1} (b) 0.935 L (935 mL) (c) 0.140 L (140 mL)
10. $7.34 \times 10^{-2} \text{ mol L}^{-1}$
11. 25.2 mL of KOH
12. 57.5%
13. 192 g mol^{-1}
14. $0.954 \text{ g of Na}_2\text{CO}_3$

Set 16 : Acid-bases titrations 2

1. $[\text{Acid}] = 1.38 \times 10^{-5} \text{ mol L}^{-1}$
3. $[\text{HCO}_3^-] = 6.32 \times 10^{-6} \text{ mol L}^{-1}$
5. $[\text{lactic acid}] = 9.97 \times 10^{-6} \text{ mol L}^{-1}$
7. $[\text{H}_3\text{C}_6\text{H}_5\text{O}_7]_{\text{ppm}} = 31.4 \text{ ppm}$
8. (a) $\text{NH}_3(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{NH}_4^+(\text{aq})$
 (b) $\text{pH} = -\log_{10}[\text{H}^+] = -\log_{10}(8.737 \times 10^{-3}) = 2.06$
- (ii) methyl orange, methyl red or bromothymol blue.
 (iii) As the equivalence point is acidic an indicator that changes colour at a pH between about 3 and 7 is required. Methyl orange (3.1 - 4.4), methyl red (4.4 - 6.2) and bromothymol blue (3.0 - 4.6) all change colour within this range.
2. $[\text{Acid}] = 2.53 \text{ mol L}^{-1}$
4. $[\text{OH}^-] = 1.59 \times 10^{-6} \text{ mol L}^{-1}$
6. $\text{pH} = -\log_{10}[\text{H}^+] = -\log_{10}(1.12) = -1.05$



9. $[\text{Fe}]_{\text{ppm}} = 20.1 \text{ ppm}$
10. $\% \text{Pb} = 90.4\%$

Set 17: Acids and bases in action: no answers provided

Oxidation and reduction

Set 18: Oxidation number

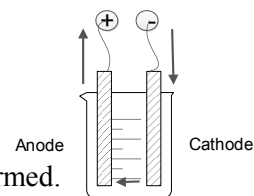
- | | | | | | |
|-----------|--------|--------|--------|--------|--------|
| 1. (a) +4 | (b) -2 | (c) +6 | (d) +2 | (e) +6 | (f) +5 |
| (g) -3 | (h) +2 | (i) +5 | (j) +5 | (k) -4 | (l) +4 |
| (m) -2 | (n) 0 | (o) +2 | (p) +4 | (q) +1 | (r) -3 |
| (s) +5 | (t) -2 | (u) +4 | (v) +2 | (w) +1 | (x) +2 |
| (y) +2 | (z) +3 | | | | |
-
- | | |
|---------------------------|--|
| 2. (a) Mg (0 +2) O (0 -2) | (f) Sn (+2 +4) O (0 -2) |
| (b) Na (0 +1) H (+1 0) | (g) Br (-1 0) S (+6 +4) |
| (c) I (-1 0) C (0 -1) | (h) Fe (+2 +3) Cr (+6 +3) |
| (d) S (-2 0) N (+5 +2) | (i) None (this is an acid/base reaction) |
| (e) S (-2 0) Mn (+7 +2) | (j) N (-3 0) N (+3 0) |

Answers

2. (a) $\text{Cr} + 3\text{Ag}^+ \rightarrow \text{Cr}^{3+} + 3\text{Ag}$ $E^\circ = +1.54 \text{ V}$
 (b) $\text{Mg} + \text{Cu}^{2+} \rightarrow \text{Mg}^{2+} + \text{Cu}$ $E^\circ = +2.70 \text{ V}$
 (c) $\text{Mg} + 2\text{Ag}^+ \rightarrow \text{Mg}^{2+} + 2\text{Ag}$ $E^\circ = +3.61 \text{ V}$
 (d) $\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{Fe}^{2+} \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O} + 6\text{Fe}^{3+}$ $E^\circ = +0.59 \text{ V}$
 (e) $\text{Cl}_2 + 2\text{I}^- \rightarrow 2\text{Cl}^- + \text{I}_2$ $E^\circ = +0.82 \text{ V}$
3. (a) yes $E^\circ = +0.97$ (b) no $E^\circ = -0.94$ (c) no $E^\circ = -1.53$ (d) no $E^\circ = -0.34$
4. (a) $\text{Mg} + 2\text{H}^+ \rightarrow \text{Mg}^{2+} + \text{H}_2$ $E^\circ = +2.36 \text{ V}$
 $\text{Sn} + 2\text{H}^+ \rightarrow \text{Sn}^{2+} + \text{H}_2$ $E^\circ = +0.14 \text{ V}$
 $\text{Zn} + 2\text{H}^+ \rightarrow \text{Zn}^{2+} + \text{H}_2$ $E^\circ = +0.76 \text{ V}$
 $\text{Sr} + 2\text{H}^+ \rightarrow \text{Sr}^{2+} + \text{H}_2$ $E^\circ = +2.90 \text{ V}$
 $\text{Cu} + 2\text{H}^+ \rightarrow \text{Cu}^{2+} + \text{H}_2$ $E^\circ = -0.34 \text{ V}$
 $\text{Ag} + \text{H}^+ \rightarrow \text{Ag}^+ + \text{H}_2$ $E^\circ = -0.80 \text{ V}$
 Only those with a positive E° will be spontaneous. Mg, Sn, Zn, Sr
 (b) The total E° must be positive for the first but negative for the second.
 (i) Sn or Ni (ii) acidified H_2O_2 or MnO_4^- (iii) Pb, Sn, Ni, Co
 (iv) $\text{O}_2/4\text{H}^+$, $\text{Cr}_2\text{O}_7^{2-}$, Cl_2 (v) Au, Cl^-
5. (a) $\text{Fe}^{2+} + \text{Fe}^{2+} \rightarrow \text{Fe}^{3+} + \text{Fe}$ $E^\circ = -1.21 \text{ V}$ not spontaneous
 (b) $\text{H}_2\text{O}_2 + \text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$ $E^\circ = +1.06 \text{ V}$ spontaneous
 (c) $\text{Cl}_2 + \text{Cl}_2 \rightarrow \text{HOCl} + \text{HCl}$ $E^\circ = -0.27 \text{ V}$ not spontaneous
6. (a) $\text{Cl}_2 + 2\text{Br}^- \rightarrow 2\text{Cl}^- + \text{Br}_2$ $+0.28 \text{ V}$ (b) No reaction
 (c) $2\text{Al} + 6\text{H}^+ \rightarrow 2\text{Al}^{3+} + 3\text{H}_2$ $+1.68 \text{ V}$ (d) $\text{Fe} + \text{Sn}^{2+} \rightarrow \text{Fe}^{2+} + \text{Sn}$ $+0.30 \text{ V}$
 (e) No Reaction (f) $\text{Cr}_2\text{O}_7^{2-} + 8\text{H}^+ + 3\text{H}_2\text{S} \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O} + 3\text{S}$ $+1.19 \text{ V}$
 (g) No Reaction (h) Both Br^- and Fe^{2+} are oxidized

Set 22: Electrolytic Cells

1. (a) See diagram
 (b) Anode: $2\text{I}^-(\text{aq}) \rightarrow 2\text{e}^- + \text{I}_2(\text{aq})$ Cathode: $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$
 (c) $-0.54 + 0.34 = -0.20 \text{ V}$ The cell would require at least 0.20 V to be supplied
 (d) The blue solution would fade, salmon pink deposit on electrode and brown solution formed.



2.

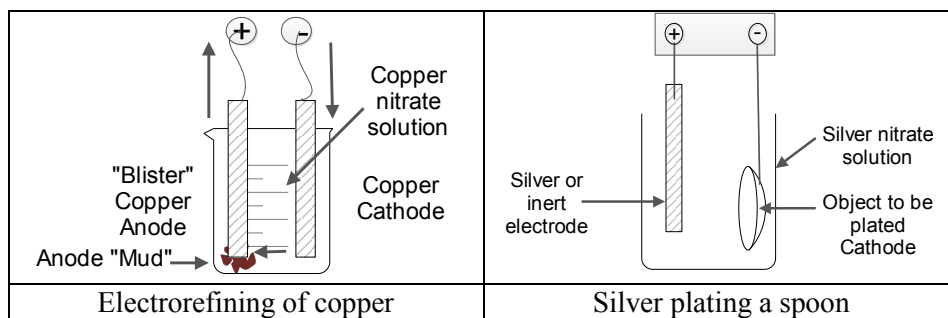
	HBr	NiI_2	KCl
Products	H_2 and Br_2	Ni and I_2	Cl_2 and K
Anode	$2\text{Br}^-(\text{aq}) \rightarrow 2\text{e}^- + \text{Br}_2(\text{aq})$	$2\text{I}^-(\text{aq}) \rightarrow \text{I}_2(\text{aq}) + 2\text{e}^-$	$2\text{Cl}^- \rightarrow 2\text{e}^- + \text{Cl}_2$
Cathode	$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$	$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Ni}(\text{s})$	$\text{K}^+ + \text{e}^- \rightarrow \text{K}$
Overall	$2\text{H}^+(\text{aq}) + 2\text{Br}^-(\text{aq}) \rightarrow \text{H}_2(\text{g}) + \text{Br}_2(\text{aq})$	$2\text{I}^-(\text{aq}) + \text{Ni}^{2+}(\text{aq}) \rightarrow \text{Ni}(\text{s}) + \text{I}_2(\text{aq})$	$2\text{K}^+ + 2\text{Cl}^- \rightarrow \text{K} + \text{Cl}_2$
Min Voltage	1.08 V	0.78 V	Cannot be determined from data sheet as not standard conditions
Observe	Colourless gas and orange solution	Colourless gas and brown solution	Green pungent gas and silver solid

	PbBr_2	CoCl_2
Products	Pb and Br_2	Co and Cl_2
Anode	$2\text{Br}^-(\text{aq}) \rightarrow 2\text{e}^- + \text{Br}_2(\text{aq})$	$2\text{Cl}^- \rightarrow 2\text{e}^- + \text{Cl}_2$
Cathode	$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Pb}(\text{s})$	$\text{Co}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Co}(\text{s})$
Overall	$\text{Pb}^{2+} + 2\text{Br}^- \rightarrow \text{Pb} + \text{Br}_2$	$\text{Co}^{2+} + 2\text{Cl}^- \rightarrow \text{Co}(\text{s}) + \text{Cl}_2(\text{g})$
Min Voltage	Cannot be determined from data sheet as not standard conditions	Cannot be determined from data sheet as not standard conditions
Observe	Red liquid and silver/grey solid	Green pungent gas and silver solid

3. (a) Aluminium metal and chlorine gas (b) Hydrogen and oxygen gas. E° favours less reactive substances

Answers

4.



Set 23: Oxidation and Reduction: no answers provided

Organic materials

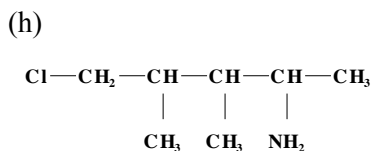
Set 24: Organic compounds

1. (a) propan-2-ol (f) 2-methylbutan-2-ol
 (b) 2-methylbutan-1-ol (g) 4-chloro-4-methylhexan-1-ol
 (c) propan-1-amine (h) 3-methylcyclopentanol
 (d) 5-methylhexan-3-ol (e) 5-chloro-4-ethylheptan-2-amine

2. (a) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ (f)
 (b) $\text{CH}_3\text{CH}_2\text{CHCH}_2\text{CH}_2\text{NH}_2$
 (c) $\begin{array}{ccccccc} \text{H} & -\text{OH} & -\text{CH}_2 & -\text{CH} & -\text{CH}_2 & -\text{OH} \\ & & & | & & & \\ & & & \text{OH} & & & \end{array}$ $\begin{array}{ccccccc} \text{CH}_3 & -\text{CH}_2 & -\text{CH} & -\text{CH}_2 & -\text{CH}_2 & -\text{NH}_2 \\ & & | & & & & \\ & & \text{CH}_2 & & & & \\ & & | & & & & \\ & & \text{CH}_3 & & & & \end{array}$



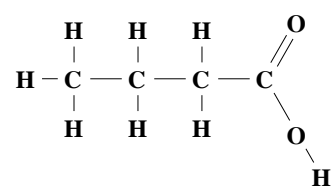
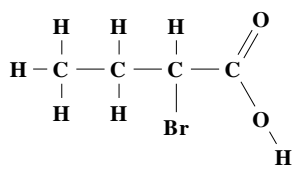
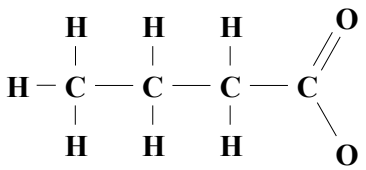
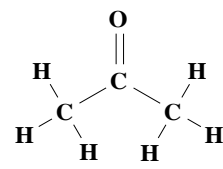
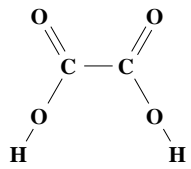
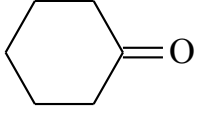
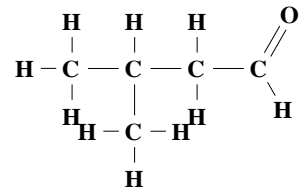
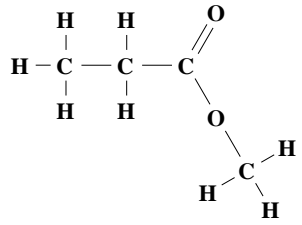
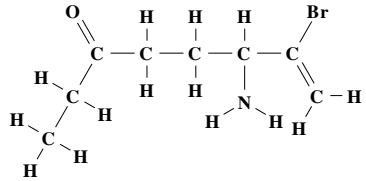
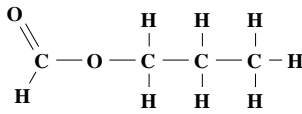
- (e) $\begin{array}{ccccc} & & \text{Cl} & & \\ & & | & & \\ \text{Cl} & -\text{CH}_2 & -\text{C} & -\text{CH}_3 \\ & & | & & \\ & & \text{NH}_2 & & \end{array}$ (g) $\begin{array}{ccccccc} & & \text{Cl} & & & & \\ & & | & & & & \\ \text{CH}_3 & -\text{CH}_2 & -\text{C} & -\text{CH}_2 & -\text{CH}_2 & -\text{CH}_2 & -\text{OH} \\ & & | & & & & \\ & & \text{CH}_3 & & & & \end{array}$



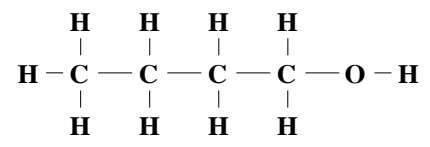
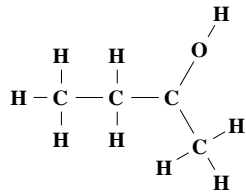
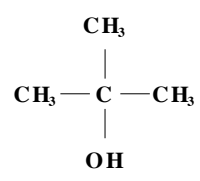
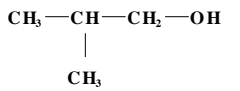
3. (a) methanal (e) butanone (butan-2-one) (i) sodium propanoate
 (b) pentan-2-one (f) 2,5-dimethylhexan-3-one (j) methyl ethanoate
 (c) propanal (g) butanoic acid
 (d) 2-chloro-4-methylhexanal (h) 3-chloropropanoic acid

Answers

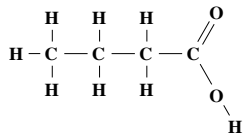
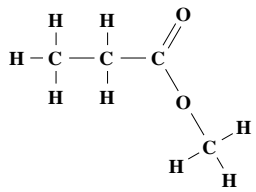
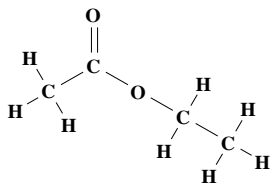
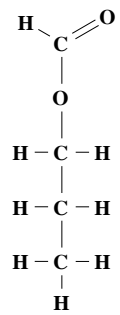
4.

<p>(a)</p> 	<p>(e)</p> 	<p>(i)</p> 
<p>(b)</p> 	<p>(f)</p> 	<p>(j)</p> 
<p>(c)</p> 	<p>(g)</p> 	
<p>(d)</p> 	<p>(h)</p> 	

5 (a)

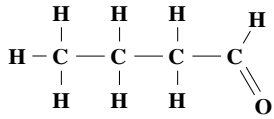
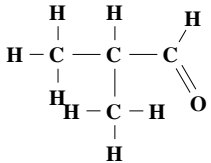
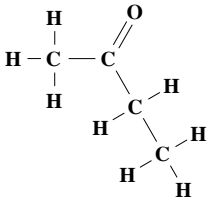
	 <p style="text-align: center;"><chem>CH3CH2COHCH3</chem></p>	 <p style="text-align: center;"><chem>CH3C(CH3)OHCH3</chem></p>	 <p style="text-align: center;"><chem>CH3CH(CH3)CH2OH</chem></p>
butan-1-ol	Butan-2-ol	2-methylbutan-2-ol	2-methylpropan-1-ol

5 (b)

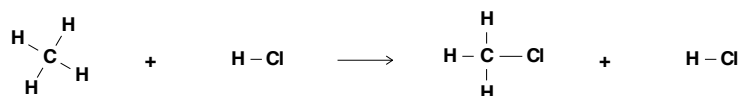
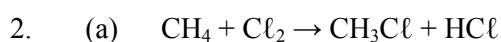
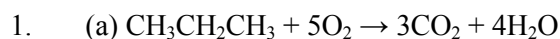
			
butanoic acid	methyl propanoate	ethyl ethanoate	propyl methanoate

Answers

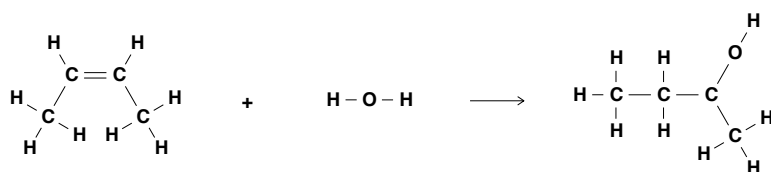
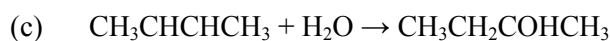
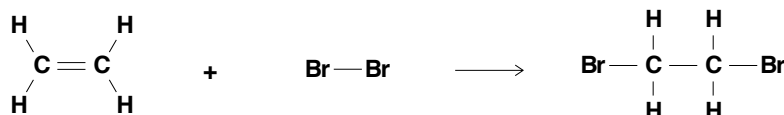
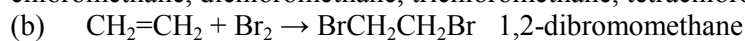
5 (c)

		
butanal	methyl propanal	butan-2-one

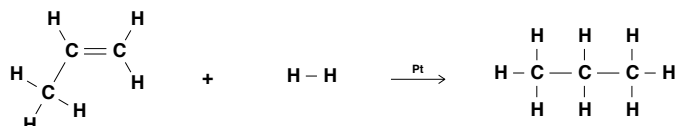
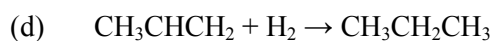
Set 25: Reactions of organic compounds



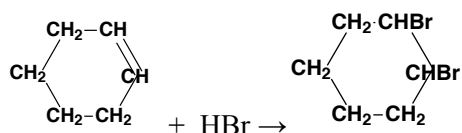
chloromethane, dichloromethane, trichloromethane, tetrachloromethane



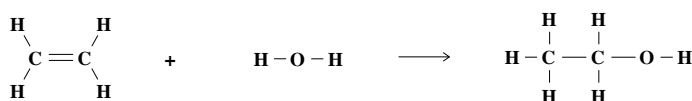
Butan-2-ol



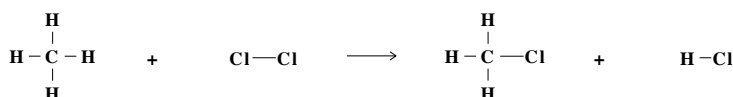
Propane



3. (a) ethene and water.



(b) Step 1: methane, chlorine, ultraviolet light.

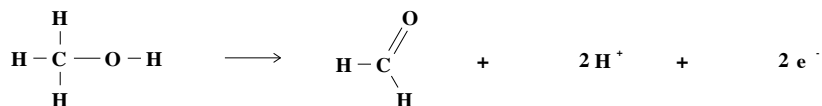


Answers

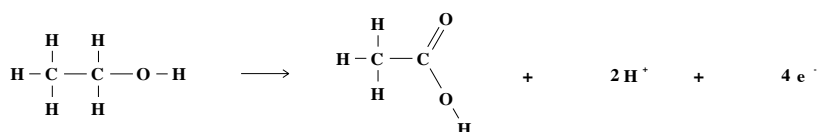
Step 2: chloromethane, fluorine and ultraviolet light.



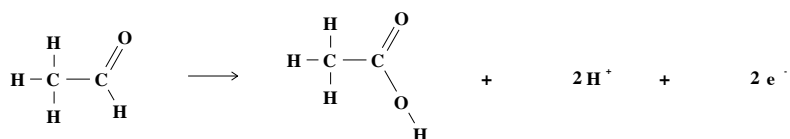
4. (a)



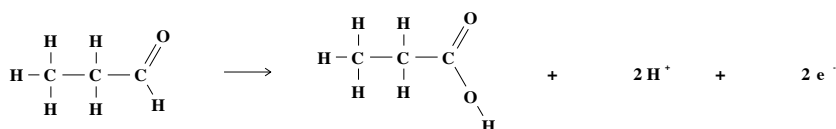
(b)



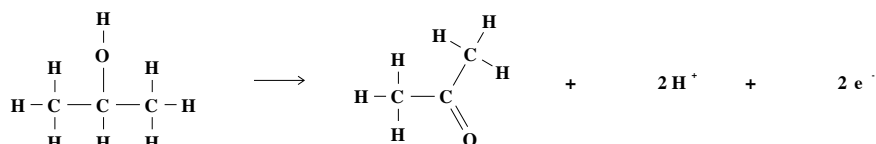
(c)



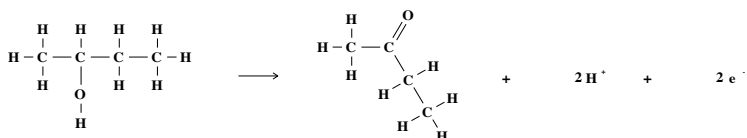
(d)



(e)



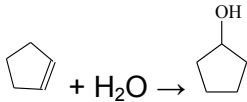
(f)



5. (a) $5\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COH} + 2\text{MnO}_4^- + 6\text{H}^+ \rightarrow 5\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH} + 2\text{Mn}^{2+} + 3\text{H}_2\text{O}$ pentanoic acid
 (b) $5\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + 4\text{MnO}_4^- + 12\text{H}^+ \rightarrow 5\text{CH}_3\text{CH}_2\text{COOH} + 4\text{Mn}^{2+} + 11\text{H}_2\text{O}$ propanoic acid
 (c) $5\text{CH}_3\text{CHOHCH}_3 + 2\text{MnO}_4^- + 6\text{H}^+ \rightarrow 5\text{CH}_3\text{COCH}_3 + 2\text{Mn}^{2+} + 8\text{H}_2\text{O}$ propanone
 (d) $3\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{Cr}_2\text{O}_7^{2-} + 8\text{H}^+ \rightarrow 3\text{CH}_3\text{CH}_2\text{CH}_2\text{CCHO} + 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$ butanal
 (e) $3\text{CH}_3\text{CCHO} + \text{Cr}_2\text{O}_7^{2-} + 8\text{H}^+ \rightarrow 3\text{CH}_3\text{COOH} + 2\text{Cr}^{3+} + 4\text{H}_2\text{O}$ ethanoic acid
 (f) $3\text{CH}_3\text{OH} + 2\text{Cr}_2\text{O}_7^{2-} + 16\text{H}^+ \rightarrow 3\text{HCOOH} + 4\text{Cr}^{3+} + 11\text{H}_2\text{O}$ methanoic acid
 (g) $3\text{CH}_3\text{CHOHCH}_2\text{CH}_3 + \text{Cr}_2\text{O}_7^{2-} + 8\text{H}^+ \rightarrow 3\text{CH}_3\text{COCH}_2\text{CH}_3 + 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$ butan-2-one
 (h) $5\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + 2\text{MnO}_4^- + 6\text{H}^+ \rightarrow 5\text{CH}_3\text{CH}_2\text{CHO} + 2\text{Mn}^{2+} + 8\text{H}_2\text{O}$ propanal

6. (a) $2\text{CH}_3\text{OH} + 2\text{Na} \rightarrow \text{H}_2 + 2\text{CH}_3\text{O}^- + 2\text{Na}^+$ methoxide ion
 (b) $2\text{CH}_3\text{CHOHCH}_3 + 2\text{Na} \rightarrow \text{H}_2 + 2\text{CH}_3(\text{ONa})\text{CHCH}_3$ sodium prop-2-oxide
 (c) $\text{CH}_3\text{CH}_2\text{COOH} + \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} \xrightarrow{-\text{H}^+} \text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_2\text{CH}_2\text{CH}_3 + \text{H}_2\text{O}$ butyl propanoate
 (d) $\text{HCOOH} + \text{CH}_3\text{CHOHCH}_3 \rightarrow \text{HCOOCH}(\text{CH}_3)\text{CH}_3 + \text{H}_2\text{O}$ 2-propyl methanoate
 (e) $\text{CH}_3\text{CH}_2\text{COOH} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}_2\text{COO}^- + \text{H}_2\text{O}$ propanoate ion
 (f) $\text{CH}_3\text{COO}^- + \text{H}^+ \rightarrow \text{CH}_3\text{COOH}$ ethanoic acid

Answers

7. (a) butan-2-ol, and acidified MnO_4^- or acidified $\text{Cr}_2\text{O}_7^{2-}$.
 $5\text{CH}_3\text{CHOHCH}_2\text{CH}_3 + 2\text{MnO}_4^- + 6\text{H}^+ \rightarrow 5\text{CH}_3\text{COCH}_2\text{CH}_3 + 2\text{Mn}^{2+} + 8\text{H}_2\text{O}$
- (b) methane, CH_4 , and chlorine. $\text{CH}_4 + \text{Cl}_2 \rightarrow \text{CH}_3\text{Cl} + \text{HCl}$ then
 $\text{CH}_3\text{Cl} + \text{Cl}_2 \rightarrow \text{CH}_2\text{Cl}_2 + \text{HCl}$ finally $\text{CH}_2\text{Cl}_2 + \text{Cl}_2 \rightarrow \text{CHCl}_3 + \text{HCl}$
- (c) pentan-1-ol, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$, and acidified MnO_4^- or acidified $\text{Cr}_2\text{O}_7^{2-}$.
 $5\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + 4\text{MnO}_4^- + 12\text{H}^+ \rightarrow 5\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COOH} + 4\text{Mn}^{2+} + 11\text{H}_2\text{O}$
- (d) propanoic acid, propan-1-ol, $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ and conc sulfuric acid.
 $\text{CH}_3\text{CH}_2\text{COOH} + \text{CH}_3\text{CH}_2\text{CH}_2\text{OH} \rightarrow \text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_3 + \text{H}_2\text{O}$
- (e) Cyclopentene and water.
- 
- (f) hex-2-ene, $\text{CH}_3\text{CH}=\text{CHCH}_2\text{CH}_2\text{CH}_3$ and bromine.
 $\text{CH}_3\text{CH}=\text{CHCH}_2\text{CH}_2\text{CH}_3 + \text{Br}_2 \rightarrow \text{CH}_3\text{CHBrCHBrCH}_2\text{CH}_2\text{CH}_3$
- (g) propene, $\text{CH}_3\text{CH}=\text{CH}_2$ and hydrogen chloride: $\text{CH}_3\text{CH}=\text{CH}_2 + \text{HCl} \rightarrow \text{CH}_3\text{CHClCH}_3$
- (h) pentan-1-ol, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$, and acidified $\text{Cr}_2\text{O}_7^{2-}$ in limited quantities.
 $3\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{Cr}_2\text{O}_7^{2-} + 8\text{H}^+ \rightarrow 3\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CHO} + 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$
- (i) ethanol, $\text{CH}_3\text{CH}_2\text{OH}$, methanoic acid and sulfuric acid: $\text{CH}_3\text{CH}_2\text{OH} + \text{HCOOH} \rightarrow \text{HCOOCH}_2\text{CH}_3 + \text{H}_2\text{O}$
- (j) but-1-ene, $\text{CH}_2=\text{CHCH}_2\text{CH}_3$, and water: $\text{CH}_2=\text{CHCH}_2\text{CH}_3 + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{CHOHCH}_2\text{CH}_3$

Set 26: Calculations involving carbon compounds

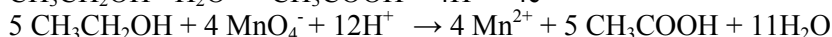
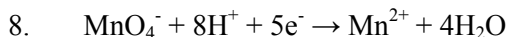
1. $\text{CH}_3\text{CH}=\text{CH}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
 $n(\text{propanol}) = m/M = 1000 / 60.09 = 16.64 \text{ mol}$
 $m(\text{CH}_3\text{CH}=\text{CH}_2) = nM = 16.64 \times 42.078 = 700.1 \text{ g} = 0.700 \text{ kg}$
2. $2\text{CH}_3\text{OH} + 2\text{Na} \rightarrow 2\text{CH}_3\text{ONa} + \text{H}_2$
- (a) $n(\text{CH}_3\text{OH}) = m/M = 250 / 32.04 = 7.803 \text{ mol}$
 $m(\text{CH}_3\text{ONa}) = nM = 7.803 \times 54.024 = 42155 = 422 \text{ g}$
- (b) $n(\text{H}_2) = \frac{1}{2} n(\text{CH}_3\text{OH})$
 $V(\text{H}_2)_{\text{stp}} = n \times 22.71 = 3.901 \times 22.71 = 88.6 \text{ L}$
- (c) Using $PV = nRT$, $V = nRT/P = 7.803 \times 8.314 \times (273+23.0) / 102.4 = V_2 = 93.8 \text{ L}$
3. $\text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}$
 $V(\text{CO}_2) = 3V(\text{C}_3\text{H}_8) = 3 \times 1.00 = 3.00 \text{ L}$
4. $\text{CH}_3(\text{CH}_2)_{11}\text{C}_6\text{H}_4\text{SO}_3\text{H} + \text{NaOH} \rightarrow \text{CH}_3(\text{CH}_2)_{11}\text{C}_6\text{H}_4\text{SO}_3\text{Na} + \text{H}_2\text{O}$
- (a) Sulfonic acid : $n = m/M = 196 \text{ mol}$
 Sodium hydroxide : $n = m/M = 8500 / 39.99 = 212.6 \text{ mol}$
 $\therefore \text{NaOH}$ is INXS and sulfonic acid is the limiting reagent
 $m(\text{CH}_3(\text{CH}_2)_{11}\text{C}_6\text{H}_4\text{SO}_3\text{Na}) = 348.5 \times 196 = 68.3 \text{ kg}$
- (b) $m(\text{NaOH})_{\text{left}} = 212.6 - 196 = 16.6 \text{ mol}$
 $M = n \times M = 16.6 \times 39.99 = 664 \text{ g} = 0.664 \text{ kg}$
5. (a) $n[\text{C}_{10}\text{H}_8] = m/M = 50.0 / 128.2 = 0.3900 \text{ mol}$
 $= n/v = 0.3900 / 0.250 = 1.56 \text{ mol L}^{-1}$
- (b) $C_1V_1 = C_2V_2 = 1.56 \times 0.25 = 2.80 \times V_2$
 $\therefore V_2 = 0.1393 \text{ L}$
 $V(\text{H}_2\text{O})_{\text{to remove}} = V_1 - V_2 = 0.250 - 0.1393 = 0.1106 = 0.111 \text{ L} = 111 \text{ mL}$
6. $2(\text{CH}_3(\text{CH}_2)_{16}\text{COONa}(\text{aq}) + \text{CaCl}_2(\text{aq}) \rightarrow ((\text{CH}_3(\text{CH}_2)_{16}\text{COO})_2\text{Ca}(\text{s}) + 2\text{NaCl}(\text{aq}))$
 $n((\text{CH}_3(\text{CH}_2)_{16}\text{COO})_2\text{Ca}) = m/M = 1.25 / 607.02 = 2.059 \times 10^{-3} \text{ mol}$
 \therefore there was $2 \times 2.059 \times 10^{-3} \text{ mol}$ of soap
 $M = n \times M = 2 \times 2.059 \times 10^{-3} \times 306.45 = 1.262 \text{ g soap}$
 $\% = \text{soap} / \text{mixture} \times 100 = 1.262 / 10.0 \times 100 = 12.6\%$

Answers



(a) $n(\text{NaOH}) = c \times V = 1.506 \times 10^{-5} \times 0.01635 = 2.462 \times 10^{-7} \text{ mol NaOH used}$
 As mol ratio is 1:1 there were $2.462 \times 10^{-7} \text{ mol HTa in 20 mL must}$
 $[\text{titratable acid}] = n/V = 2.462 \times 10^{-7} / 0.02 = 1.23 \times 10^{-5} \text{ mol L}^{-1}$

(b) Ionised to 2% means there is $1.23 \times 10^{-5} \times 0.02 = 2.46 \times 10^{-3} \text{ mol H}^+$
 $\text{pH} = 2.609$



5.00 mL sample	Diluted to 500 mL	20 mL sample taken
----------------	-------------------	--------------------

Titres: 23.56, 23.38, 23.12, 23.05 So mean of last two = 23.085 mL

$n(\text{MnO}_4^-) = c \times V = 0.0216 \times 0.023085 = 0.000498636 \text{ mol}$

\therefore as MR = 4:5 there was $5/4 \times 0.000498636 \text{ mol alcohol in the 20 mL sample} = 0.000623295 \text{ mol}$

So in the whole 500 mL there was $25 \times 0.000623295 = 0.015582375 \text{ mol in 5 mL wine}$

So in 1L there was $200 \times 0.015582375 = 3.116 \text{ mol L}^{-1} = 3.12 \text{ mol L}^{-1}$

(b) $[\text{CH}_3\text{CH}_2\text{OH}]_{\text{wine in g per L}} = n \times M = 3.12 \times 46.06 = 144 \text{ g L}^{-1}$



25.00 mL sample	Diluted to 250 mL	20 mL sample taken
-----------------	-------------------	--------------------

Titres : 25.08, 24.86, 25.13, 24.79, 24.88 Mean of last 4 = 24.915 mL

$n(\text{HCl}) = c \times V = 0.0507 \times 0.024915 = 0.001263 \text{ mol HCl}$

\therefore there were 0.001263 mol of methanamine in the 20 mL sample

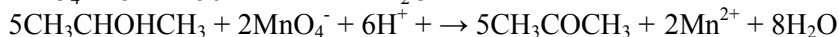
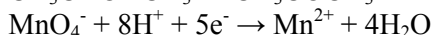
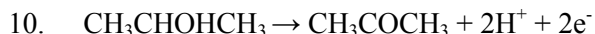
\therefore in the diluted sample there were $12\frac{1}{2}$ times as much = $12.5 \times 0.001263 = 0.0157899 \text{ mol methanamine in 25 mL original sample}$

\therefore in 1L there was $40 \times$ as much = $40 \times 0.0157899 = 0.632 \text{ mol L}^{-1}$

(b) $m = n \times M = 0.632 \times 31.0571 = 19.628 \text{ g / L}$

$\rho = m/V$ so $m = \rho \times V = 1.07 \times 1000 = 1070 \text{ g/L}$

$\%(\text{CH}_3\text{NH}_2) = 19.628 / 1070 \times 100 = 1.83 \%$



5.00 mL sample	Diluted to 250 mL	20 mL sample taken
----------------	-------------------	--------------------

$n(\text{MnO}_4^-) = c \times V = 0.0203 \times 0.02873 = 0.0005832 \text{ mol}$

As MR is 2: 5 there were $5/2 \times 0.0005832 \text{ mol propan-2-ol in the 20 mL sample}$
 $= 0.001458 \text{ mol}$

\therefore in the 250 mL solution there was $12\frac{1}{2}$ times as much = $12.5 \times 0.001458 = 0.018225 \text{ mol}$

This was originally from a 5.00 mL

$C = n/V = 0.018225 / 0.005 = 3.645 \text{ mol L}^{-1}$ in the original substance

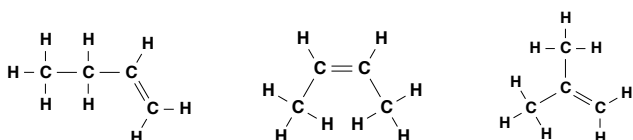
$m = n \times M = 3.645 \times 60.0950 = 219 \text{ g L}^{-1}$

Set 27: Empirical, molecular and structural formula

1. (a) Let there be 100 g of substance

Symbol	Mass	Mol
C	85.7g	$85.7/12.01 = 7.1357$
H	14.3 g	$14.3 / 1.008 = 14.186$
Ratio = 1:2 ∴ the Empirical Formula is CH ₂		

- (b) $PV = nRT$ so $n = PV / RT = (105 \times 1.18) / (8.314 \times 298) = 0.0500$ mol
 If 2.80 g is 0.005 mol then 1 mol is $2.80/0.05 = 56$ g
 Mass of the EF is 14 – the MF mass is 56. The ratio is 4:1 so the MF is C₄H₈



- (c)

- (d) Bromine adds to atoms either end of the double bond so the double bond is between atoms 2 and 3 therefore formula is but-2-ene

2. (a)

CHO	+	O ₂	→	CO ₂	+	H ₂ O
3.45 g				6.6 g		4.05 g
- 1.802 C				$n = m/M$		$n = m/M$
-0.45337 H				$= 6.6/44 = 0.1500$		$= 4.05/18.01$
				mol		$= 0.22487$ mol H ₂ O
∴ 1.19463 g of O				∴ 0.150 mol of C		∴ 0.4498 mol of H
$n = m/M = 1.19463 / 16 =$				$m = n \times M = 0.150 \times$		$= 0.45337$ g of H
0.0747 mol				12.01 = 1.802 g of C		

C_{0.150}H_{0.4498}O_{0.0747} divide though by 0.0747 = C₂H₆O₁

- (b) $PV = nRT$ so $n = PV / RT = (98.0 \times 0.950) / (8.314 \times 373) = 0.030021$ mol
 If 1.38 g is 0.0300 mol then 1 mol is $1.38/0.03 = 46$ g
 $M_r(C_2H_6O) = 46.068$ Relative molecular mass is the same as the relative empirical formula mass so the molecular formula is C₂H₆O

- (c) Possible structures include: CH₃CH₂OH and CH₃-O-CH₃

- (d) CH₃CH₂OH

3. (a)

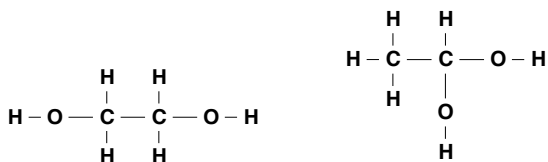
CHO	+	O ₂	→	CO ₂	+	H ₂ O
0.682 g				0.968 g		0.594 g
- 0.2642 g C				$n = m/M$		$n = m/M$
-0.06649 g H				$= 0.968/44 = 0.022$		$= 0.594/18.01$
				mol		$= 0.03298$ mol H ₂ O
∴ 0.35131 g of O				∴ 0.022 mol of C		∴ 0.06596 mol of H
$n = m/M = 0.35131 / 16 =$				$m = n \times M = 0.022 \times$		$= 0.06649$ g of H
0.021956 mol				12.01 = 0.2642 g of		
				C		

Formula : C_{0.022}H_{0.06596}O_{0.021956} = CH₃O

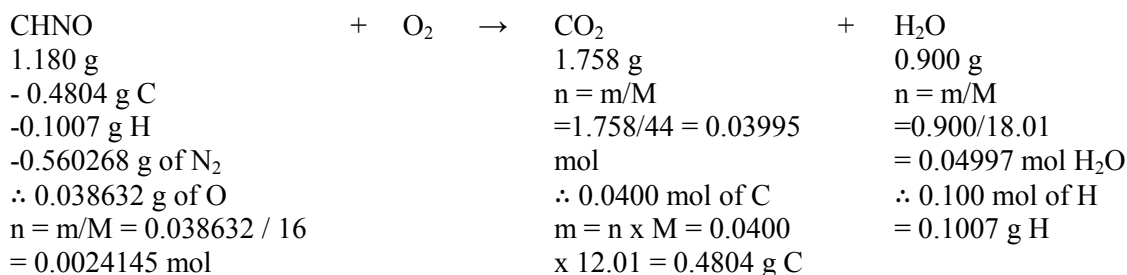
- (b) For 0.744 g sample
 $PV = nRT$ so $n = PV / RT = (95.0 \times 0.497) / (8.314 \times 473) = 0.0120062$ mol
 If 0.744 g is 0.0120062 mol then 1 mol is $0.744 / 0.0120062 = 61.97$ g
 $M_r = 61.975$, C₂H₆O

Answers

(c) Possible structures are.



4.



A second sample: 1.180 g

$$n = PV / RT = (105.0 \times 0.471) / (8.314 \times 298) = 0.0200 \text{ mol nitrogen gas N}_2$$

$$m = n \times M = 0.0200 \times 28.013 = 0.560268 \text{ g of N}_2$$

$$n(\text{N}_2) = m(\text{N}_2) / M(\text{N}_2) = 0.560268 / 28.02 = 0.02 \text{ mol}$$

$$n(\text{N}) = 2 n(\text{N}_2) = 0.04 \text{ mol}$$

(a) Empirical Formula : C_{0.0400}H_{0.100}N_{0.0400}O_{0.0024145} = **C₂H₅N₂O**

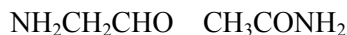
A third sample: 0.5896 g

$$n = PV / RT = 95.5 \times 0.281 / 8.314 \times 323.15 = 9.988 \times 10^{-3} \text{ mol}$$

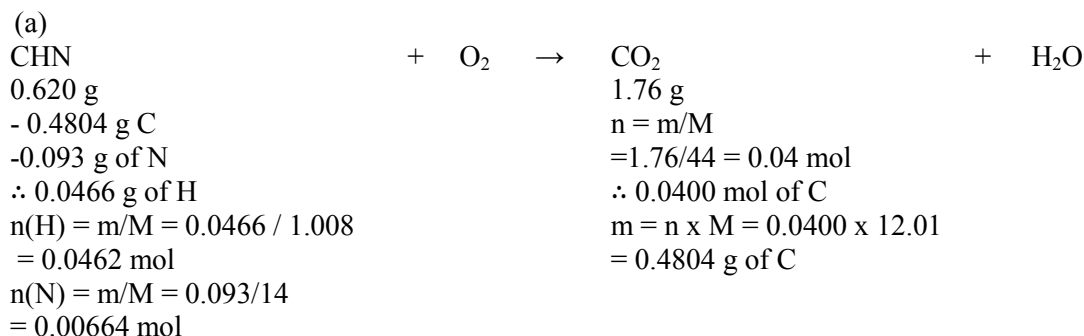
$$M = m/n = 0.5896 / 9.988 \times 10^{-3} = 59.03$$

(b) E.F. mass = 73 yet M = 59 as per sample 3 the Molecular formula C₂H₅NO has M = 59 but this is not the EF based on sample 2 so there is an error in the question.

(c) Possible structures for a compound with this molecular formula, C₂H₅NO include.



5.



2nd sample

$$0.232 \text{ g } n = PV / RT = (101.3 \times 0.0295) / (8.314 \times 288) = 0.001248 \text{ mol gas N}_2$$

$$m(\text{N}_2) = n \times M = 0.001248 \times 28.01 = 0.0349 \text{ g}$$

$$\therefore \% \text{ N}_2 = 0.0349 / 0.232 \times 100 = 15.04\%$$

∴ in the original experiment there was 0.1504 x 0.620 = 0.093 g of nitrogen

Empirical Formula C_{0.0400}H_{0.0462}N_{0.00664} = **C₆H₇N**

(b) 3rd sample – let V = 1L

$$n = PV / RT = (101.3 \times 1) / (8.314 \times 373) = 0.03266$$

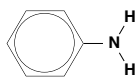
$$\rho = m / v \text{ so } m = \rho \times V = 3.04 \text{ g}$$

$$\therefore 3.04 \text{ g} = 0.03266 \text{ mol}$$

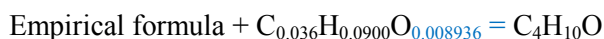
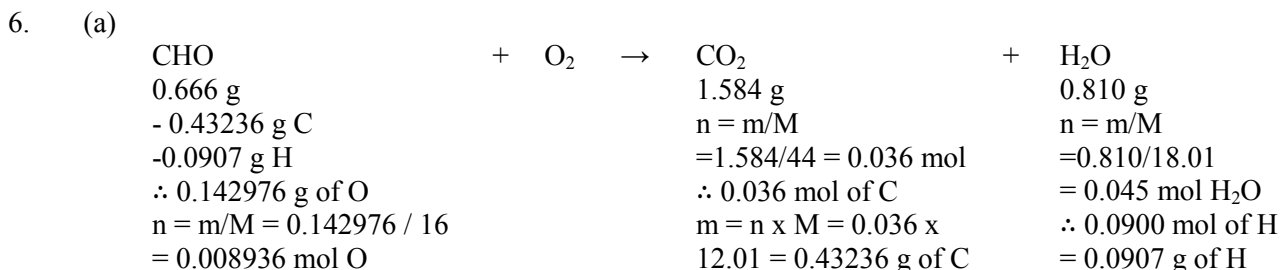
$$\text{So } 1 \text{ mol} = 93.080 \text{ g}$$

$$M_r(\text{C}_6\text{H}_7\text{N}) = 93.126, \quad \text{So Molecular formula} = \text{Empirical Formula} = \text{C}_6\text{H}_7\text{N}$$

Answers

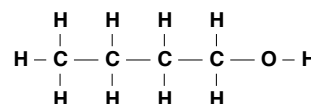


(c) A possible structure ..

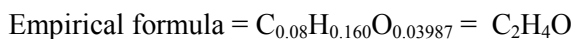
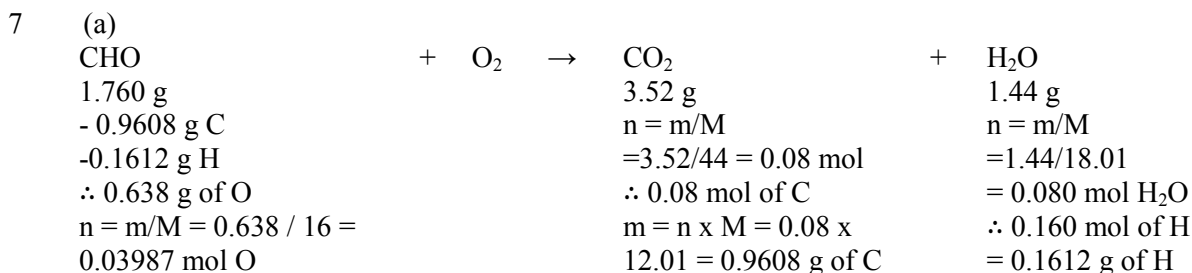
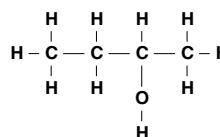


(b) Let there be 1L of gas
 $n = PV / RT = (101.3 \times 1) / (8.314 \times 473) = 0.025759$
 $\rho = m / v$ so $m = \rho \times V = 1.91 \text{ g}$
 $\therefore 1.91 \text{ g} = 0.025759 \text{ mol}$ so $1 \text{ mol} = 1.91 / 0.025759 = 74.148$
 $M_r(\text{C}_4\text{H}_{10}\text{O}) = 74.12$ so $\text{MF} = \text{EF} = \text{C}_4\text{H}_{10}\text{O}$

(c) There are 7 isomers including:
 butan-1-ol, butan-2-ol, 2-methyl-propan-1-ol,
 2,2-dimethylpropan-2-ol

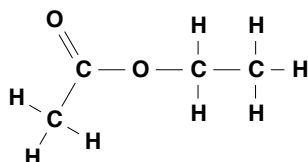


(d) Based on the observed reactivity the structure of the compound is



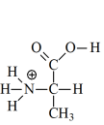
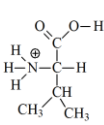
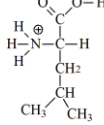
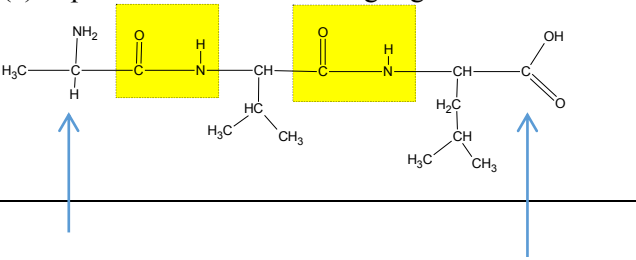
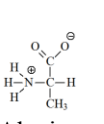
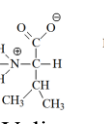
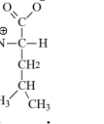
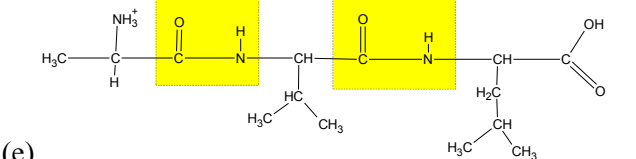
Let there be 1L of gas
 $n = PV / RT = (105.0 \times 1) / (8.314 \times 423) = 0.02985 \text{ mol}$
 $\rho = m / v$ so $m = \rho \times V = 2.62 \text{ g}$
 $\therefore 2.62 \text{ g} = 0.02985 \text{ mol}$ so $1 \text{ mol} = 2.62 / 0.02985 = 87.7721$
 $M_r(\text{C}_2\text{H}_4\text{O}) = 44.0526 \therefore \text{MF} = \text{EF} \times 2 = \text{C}_4\text{H}_8\text{O}_2$

(c) Three solutions all esters e.g.

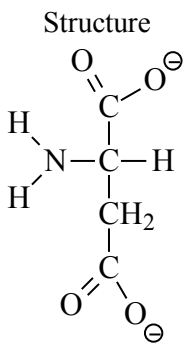
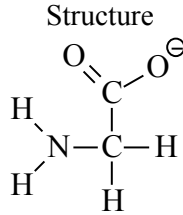
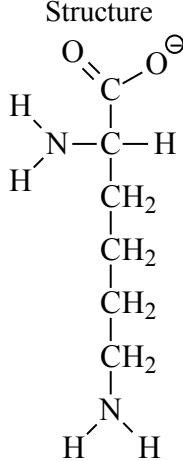


Answers

Set 28: Amino Acids

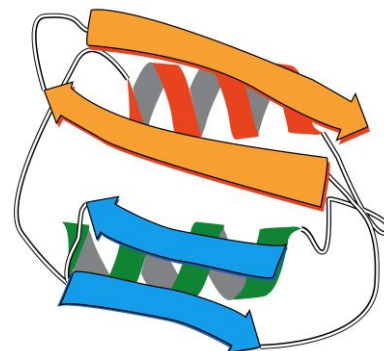
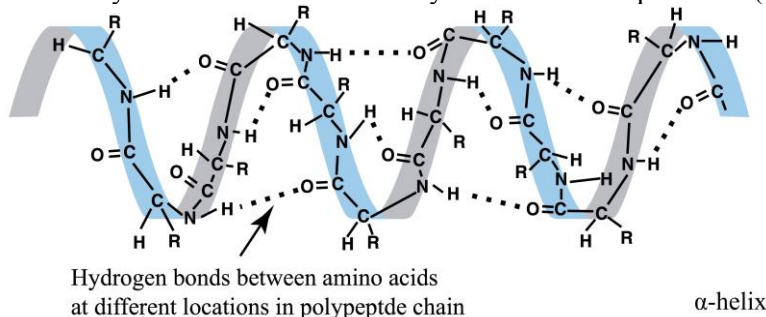
<p>1.</p> <p>(a) Acid forms (pH3):</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>Alanine</p> </div> <div style="text-align: center;">  <p>Valine</p> </div> <div style="text-align: center;">  <p>Leucine</p> </div> </div>	<p>(c) Peptide bonds are shown highlighted</p> 
<p>(b) Zwitterion forms:</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>Alanine</p> </div> <div style="text-align: center;">  <p>Valine</p> </div> <div style="text-align: center;">  <p>Leucine</p> </div> </div>	<p>(d) amino terminus ----- carboxy terminus By convention, peptides are names from the amino to the carboxy terminus</p>
	<p>(e)</p> 

- Enzymes are biological catalysts that speed up chemical reactions. In biological systems, other ways of speeding up reactions, such as increasing temperature, concentration or pressure are often not achievable without killing the organism. Without enzyme catalysts, many cellular reactions would not take place under cellular conditions.
- 3 – you would need a water molecule to break each peptide bond (as one water was released when each peptide bond was formed)
- 99 - one water molecule is created with each peptide bond formed, so 1 water is released when the first 2 amino acids join then one water is released for each peptide bond formed when adding an addition amino acid.
-

Name	Symbol	Name	Symbol	Name	Symbol
aspartic acid	Asp	glycine	Gly	lysine	Lys
<p>Structure</p> 		<p>Structure</p> 		<p>Structure</p> 	

Set 29: Proteins

- 1.
- The primary structure is the linear sequence of amino acid residues in a protein.
 - The secondary structure is the structure that arises from the arrangement of hydrogen bonds that occurs between the oxygen and the hydrogen atoms of the amide bonds that occur in the proteins backbone. Oxygen's and hydrogen's on the side chains also form hydrogen bonds, but these ones do not participate in secondary structure. Some secondary structures are alpha helix (shown below) and beta sheet.



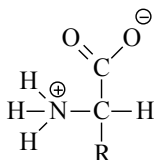
- The tertiary structure is the overall shape that a polypeptide chain forms. This shape arises largely through the interactions of the side chains, and includes hydrogen bonding, hydrophobic interactions, ionic bonding (NH_3^+ COO^-), and disulphide bonding between cysteine side chains (cys-S-S-cys). See figure opposite.

2.

Protein structure	Bonding forces
Primary	covalent bonds
Secondary	hydrogen bonds
Tertiary	dispersion forces, hydrogen bonds, ionic bonds, disulfide bonds

- 3.
- The α -helix secondary structure, every N-H group donates a hydrogen bond to the C=O group of an amino acid four residues earlier in the chain. Beta sheets consist of strands connected by at least two backbone hydrogen bonds, forming a pleated sheet
 - A quaternary structure because there are multiple peptide chains (protein molecules) in each complex.
 - Glutamic acid is hydrophilic and would aggregate around water molecules, valine is hydrophobic. It could also disrupt any hydrogen bonding or ionic bonding (salt bridges) the glutamic acid residue was involved in.
4. The different amino acid sequences and consequently their 3d structure, makes different proteins unique.
5. A protein's shape is determined by its sequence of amino acids. The different side chains on these determine the mix of hydrogen bonds, ionic bonds, disulfide bridges or dispersion forces that give it its shape.

6. (a)



- (b) The length and nature of the amino acids and their affinity for other species.

- 7.
- α -helices are held together by hydrogen bonds.
 - N-H and C=O
 - β -sheets are held together by multiple hydrogen bonds
 - N-H and C=O
 - Hydrogen bonds are secondary bond and will rupture at high temperatures – eg: cooking meat.
8. Disulfide bridges are the strongest and most thermo stable. They are covalent bonds requiring approximately 60kJ/mole to break, compared to 20kJ/mol for hydrogen bonds.
9. The presence of concentrated sodium hydroxide will cause the amide groups to hydrolyse. This means that proteins will split into their component amino acids. At lower concentrations, hydrogen bonding and tertiary structure will be disrupted. The flesh will dissolve.

Properties, reactions and chemical synthesis

Set 30: Reaction types

1.
 - (a) $\text{CH}_3\text{COOH}(\ell) + \text{H}_2\text{O}(\ell) \rightarrow \text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$
 - (b) $\text{NH}_3(\text{g}) + \text{H}_2\text{O}(\ell) \rightarrow \text{NH}_4^+(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$ $\text{NaHCO}_3(\text{s}) \rightarrow \text{Na}^+(\text{aq}) + \text{HCO}_3^-(\text{aq})$
 - (c) $\text{NaHCO}_3(\text{s}) \rightarrow \text{HCO}_3^-(\text{aq}) + \text{Na}^+(\text{aq})$ $\text{HCO}_3^-(\text{aq}) + \text{H}_2\text{O}(\ell) \rightarrow \text{CO}_3^{2-}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$
 - (d) $\text{NaHSO}_4(\text{s}) \rightarrow \text{Na}^+(\text{aq}) + \text{HSO}_4^-(\text{aq})$ $\text{HSO}_4^-(\text{aq}) + \text{H}_2\text{O}(\ell) \rightarrow \text{SO}_4^{2-}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$
 - (e) $\text{K}_2\text{CO}_3(\text{s}) \rightarrow 2\text{K}^+(\text{aq}) + \text{CO}_3^{2-}(\text{aq})$ $\text{CO}_3^{2-}(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{HCO}_3^-(\text{aq}) + \text{OH}^-(\text{aq})$
 - (f) $\text{NH}_4\text{CH}_3\text{COO}(\text{s}) \rightarrow \text{NH}_4^+(\text{aq}) + \text{CH}_3\text{COO}^-(\text{aq})$ $\text{NH}_4^+(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{NH}_3(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$
 $\text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{CH}_3\text{COOH}(\text{aq}) + \text{OH}^-(\text{aq})$

2.
 - (a)
 - i) $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\ell)$
 - ii) Two colourless solutions are mixed together. No visible reaction; some heat evolved.
 - (b)
 - i) $\text{Ba}(\text{OH})_2(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Ba}^{2+}(\text{aq}) + 2\text{H}_2\text{O}(\ell)$
 - ii) A white solid dissolves in a colourless solution.
 - (c)
 - i) $\text{MgO}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{H}_2\text{O}(\ell)$
 - ii) A white solid dissolves in a colourless solution.
 - (d)
 - i) $\text{CH}_3\text{COOH}(\text{aq}) + \text{NH}_3(\text{aq}) \rightarrow \text{NH}_4^+(\text{aq}) + \text{CH}_3\text{COO}^-(\text{aq})$
 - ii) Two colourless solutions mixed. No visible reactions. There is a reduction in the vinegar smell.
 - (e)
 - i) $\text{Zn}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{H}_2(\text{g})$
 - ii) A silver solid dissolves in a colourless solution; colourless, odourless gas evolved
 - (f)
 - i) $2\text{CH}_3\text{COOH}(\text{aq}) + \text{Mg}(\text{s}) \rightarrow \text{Mg}^{2+}(\text{aq}) + 2\text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_2(\text{g})$
 - ii) A silver solid dissolves in a colourless solution; colourless, odourless gas evolved.
 - (g)
 - i) $\text{Cu}(\text{s}) + 4\text{H}^+(\text{aq}) + 2\text{NO}_3^-(\text{aq}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{NO}_2(\text{g}) + 2\text{H}_2\text{O}(\ell)$
 - ii) Brown solid dissolves in colourless solution to produce brown, pungent gas and a blue solution.
 - (h)
 - i) $\text{Ni}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Ni}^{2+}(\text{aq}) + \text{H}_2(\text{g})$
 - ii) Silver solid dissolves in colourless solution forms colourless, odourless gas and green solution.
 - (i)
 - i) $\text{Fe}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Fe}^{2+}(\text{aq}) + \text{H}_2(\text{g})$
 - ii) Silver solid dissolves in colourless solution, colourless, odourless gas evolved and a pale green soln.

3.
 - (a)
 - i) $\text{Br}_2(\ell) + 2\text{I}^-(\text{aq}) \rightarrow 2\text{Br}^-(\text{aq}) + \text{I}_2(\text{s})$
 - ii) Brown/orange liquid added to colourless solution. Brown/orange fades and dark brown solid forms
 - (b)
 - i) $\text{Mg}(\text{s}) + \text{Fe}^{2+}(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{Fe}(\text{s})$
 - ii) Silver solid to pale green solution. Black precipitate on silver solid; pale-green soln to colourless.
 - (c)
 - i) $\text{Cu}(\text{s}) + 2\text{Ag}^+(\text{aq}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{Ag}(\text{s})$
 - ii) Brown solid to colourless solution. Black precipitate on brown solid; colourless solution turns blue.
 - (d)
 - i) $\text{Zn}(\text{s}) + \text{Ni}^{2+}(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{Ni}(\text{s})$
 - ii) Silver solid to green solution. Black precipitate on silver solid; green solution fades to colourless.
 - (e)
 - i) $2\text{Na}(\text{s}) + 2\text{H}_2\text{O}(\ell) \rightarrow 2\text{Na}^+(\text{aq}) + 2\text{OH}^-(\text{aq}) + \text{H}_2(\text{g})$
 - ii) A silver/white solid reacts vigorously with a colourless liquid to form a colourless, odourless gas.
 - (f)
 - i) $2\text{K}(\text{s}) + 2\text{H}_2\text{O}(\ell) \rightarrow 2\text{K}^+(\text{aq}) + 2\text{OH}^-(\text{aq}) + \text{H}_2(\text{g})$
 - ii) A silver/white solid reacts vigorously with a colourless liquid to produce a colourless, odourless gas.
 - (g)
 - i) $\text{Cl}_2(\text{g}) + 2\text{Br}^-(\text{aq}) \rightarrow 2\text{Cl}^-(\text{aq}) + \text{Br}_2(\text{aq})$
 - ii) A green pungent gas dissolves in a colourless solution to form a brown/orange solutions.

4.
 - (a)
 - i) $\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})$
 - ii) Two colourless solutions are mixed to form a white precipitate.
 - (b)
 - i) $\text{Ag}^+(\text{aq}) + \text{Br}^-(\text{aq}) \rightarrow \text{AgBr}(\text{s})$
 - ii) Two colourless solutions are mixed to form a cream/white solid.
 - (c)
 - i) $\text{Pb}^{2+}(\text{aq}) + 2\text{I}^-(\text{aq}) \rightarrow \text{PbI}_2(\text{s})$
 - ii) Two colourless solutions are mixed to form a yellow precipitate.
 - (d)
 - i) $\text{Ca}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{CaSO}_4(\text{s})$
 - ii) Two colourless solutions are mixed to form a white precipitate
 - (e)
 - i) $\text{Ba}^{2+}(\text{aq}) + \text{OH}^-(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + \text{H}_2\text{O}(\ell)$
 - ii) Two colourless solutions are mixed to form a white precipitate.
 - (f)
 - i) $\text{Fe}^{2+}(\text{aq}) + \text{CO}_3^{2-}(\text{aq}) \rightarrow \text{FeCO}_3(\text{s})$
 - ii) Pale green solution mixed with colourless solution forms pale green precipitate. Green solution fades.
 - (g)
 - i) $3\text{Zn}^{2+}(\text{aq}) + 2\text{PO}_4^{3-}(\text{aq}) \rightarrow \text{Zn}_3(\text{PO}_4)_2(\text{s})$

Answers

- ii) Two colourless solutions are mixed together to form a white precipitate.
- h) i) $\text{Cu}^{2+}(\text{aq}) + 2 \text{OH}^{-}(\text{aq}) \rightarrow \text{Cu}(\text{OH})_2(\text{s})$
 ii) Blue solution mixed with a colourless solution to form a blue precipitate. Blue solution colour fades.
- i) i) $2 \text{Cr}^{3+}(\text{aq}) + 3 \text{CO}_3^{2-}(\text{aq}) \rightarrow \text{Cr}_2(\text{CO}_3)_2(\text{s})$
 ii) Green solution mixed with colourless solution to form a green precipitate. Green solution colour fades.

Set 31: Percentage composition and yield

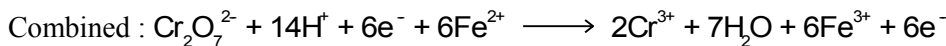
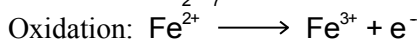
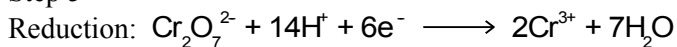
1. a) $M(\text{Fe}_2\text{O}_3) = 159.7 \text{ g mol}^{-1}$
 $\% \text{Fe} = 111.7 / 159.7 \times 100 = 69.9\%$
 b) $\% \text{Haematite} = 65 / 69.9 \times 100 = 92.9\%$
2. $\text{Zn} + 2\text{H}^{+} \rightarrow \text{Zn}^{2+} + \text{H}_2$
 $m(\text{remaining}) = m(\text{Cu}) = 0.630 \text{ g}$
 $m(\text{Zn}) = 2.71 - 0.630 = 2.08 \text{ g}$
 $\% \text{Zn} = 2.08 / 2.71 \times 100 = 76.8\%$
3. a) $n(\text{Br}_2) = 125 / (79.9 \times 2) = 0.782 \text{ mol}$
 $n(\text{C}_6\text{H}_6) = 60.0 / 78.108 = 0.768 \text{ mol}$
 1 mol of Br_2 requires 1 mol of C_6H_6
 0.782 mol of Br_2 requires 0.782 mol of C_6H_6
 $n(\text{C}_6\text{H}_6 \text{ required}) > n(\text{C}_6\text{H}_6 \text{ available})$
 C_6H_6 is LR
 $n(\text{C}_6\text{H}_5\text{Br}) = n(\text{C}_6\text{H}_6) = 0.768 \text{ mol}$
 $m(\text{C}_6\text{H}_5\text{Br}) = 0.768 \times 157 = 121 \text{ g}$
 b) $\% \text{yield} = 93.2 / 121 \times 100 = 77.3\%$
4. a) $\text{Ca}(\text{OH})_2 \rightarrow \text{CaO} + \text{H}_2\text{O}$
 b) $\% \text{CaO} = 433 / 567 \times 100 = 76.4\%$
5. a) $\text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$
 $n(\text{Ba}^{2+}) = n(\text{CuSO}_4 \cdot 5\text{H}_2\text{O})$
 $n(\text{CuSO}_4 \cdot 5\text{H}_2\text{O}) = 1.11 / 249.69 = 4.45 \times 10^{-3} \text{ mol} = n(\text{BaCl}_2)$
 $m(\text{BaCl}_2) = (4.45 \times 10^{-3}) \times (137.3 + 70.9) = 0.926 \text{ g}$
 c) $n(\text{CuCl}_2 \cdot 2\text{H}_2\text{O}) = n(\text{BaCl}_2 \text{ used}) = 4.45 \times 10^{-3} \text{ mol}$
 $m(\text{CuCl}_2 \cdot 2\text{H}_2\text{O}) = (4.45 \times 10^{-3}) \times 170.482 = 0.758 \text{ g}$
 $\% \text{yield} = 0.345 / 0.758 \times 100 = 45.5\%$
6. $n(\text{Na}_2\text{S}_2\text{O}_7) = \frac{1}{2} n(\text{S})$
 $n(\text{S}) = 17500 / 32.06 = 5.46 \times 10^2 \text{ mol}$
 $n(\text{Na}_2\text{S}_2\text{O}_7) = \frac{1}{2} (5.46 \times 10^2) = 2.73 \times 10^2 \text{ mol}$
 $m(\text{Na}_2\text{S}_2\text{O}_7) = (2.73 \times 10^2) \times (45.98 + 64.12 + 112) = 6.06 \times 10^4 \text{ g}$
 $\% \text{yield} = 50000 / 60617 \times 100 = 82.5\%$
7. let $X = m(\text{NaHCO}_3)$
 $Y = m(\text{Na}_2\text{CO}_3)$
 $X + Y = 100$
 $Y = 100 - X$
- $n(\text{Na}_2\text{CO}_3) = 90.7 / 106 = 0.856 \text{ mol}$
 $n(\text{Na}_2\text{CO}_3 \text{ total}) = \frac{1}{2} n(\text{NaHCO}_3 \text{ initial}) + n(\text{Na}_2\text{CO}_3 \text{ initial})$
 $= (\frac{1}{2} \times X / 84.01) + Y / 106$
 $0.856 = X / 168 + (100 - X) / 106$
 $62X = 1556.352$
 $X = 25.1 \text{ g}$
 $Y = 74.9 \text{ g}$
 $\% \text{Na}_2\text{CO}_3 = 74.9 / 100 \times 100 = 74.9\%$

Answers

8.

1	2	3	4	5
1.63g wire	Dissolved in acid	Made up to 250 mL	20 mL sample	Titrated with 18.1 mL of 0.0209 M $K_2Cr_2O_7$

Step 5



Mol Ratio $Cr_2O_7^{2-} : Fe = 1:6$

In 20mL sample

$n(Cr_2O_7^{2-}) = c \times v = 0.0181 \times 0.0209 = 0.0003783 \text{ mol}$

$\therefore n(Fe^{2+}) = 6 \times 0.00037829 = 0.002269 \text{ mol } Fe^{2+}$

$m(Fe) = 0.002269 \times 55.85 = 0.1267 \text{ g}$

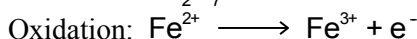
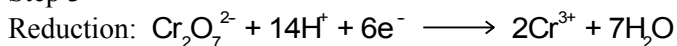
\therefore In 250 mL there was $12.5 \times 0.1267 = 1.584 \text{ g Fe}$

\therefore percentage purity of the wire = $1.5844/1.63 \times 100 = 97.2\% \text{ pure}$

9.

1	2	3
1.27 g mineral	Converted to $K_2Cr_2O_7$	Titrated with 37.5 mL of 0.400 M $FeSO_4$

Step 3



Mol Ratio $Cr_2O_7^{2-} : Fe = 1:6$

$n(Fe^{2+}) = c \times v = 0.0375 \times 0.400 = 0.015 \text{ mol } Fe^{2+}$

$\therefore n(Cr_2O_7^{2-}) = 1/6 \times 0.015 = 0.0025 \text{ mol}$

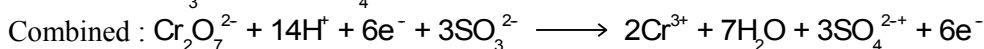
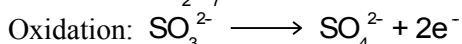
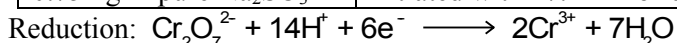
$\therefore n(Cr) = 2 \times 0.0025 = 0.005 \text{ mol}$

$\therefore m(Cr) = 52.00 \times 0.005 = 0.26 \text{ g}$

\therefore percentage purity of mineral = $0.26/1.27 \times 100 = 20.5\% \text{ pure}$

10.

1	2
0.752 g impure Na_2SO_3	Titrated with 17.2 mL of 0.0993 M $K_2Cr_2O_7$



Mol Ratio $Cr_2O_7^{2-} : SO_3^{2-} = 1:3$

$n(Cr_2O_7^{2-}) = c \times v = 0.0172 \times 0.0993 = 0.0017079 \text{ mol}$

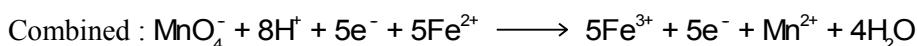
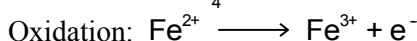
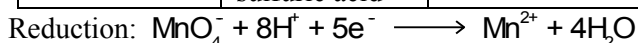
$\therefore n(SO_3^{2-}) = 3 \times 0.0017079 = 0.005123 \text{ mol}$

$\therefore m(Na_2SO_3) = 126.043 \times 0.005123 = 0.6458 \text{ g}$

\therefore percentage purity = $0.6458/0.752 \times 100 = 85.9\% \text{ pure}$

11.

1	2	3	4	5
3.08 g sample	Dissolved in sulfuric acid	Made up to 250 mL	25 mL sample	Titrated with 28.7 mL of 0.0260 M $KMnO_4$



Mol Ratio $MnO_4^- : Fe^{2+} = 1:5$

Answers

$$n(\text{MnO}_4^-) = c \times v = 0.0287 \times 0.0260 = 0.0007462 \text{ mol}$$

In 25 mL sample

$$\therefore n(\text{Fe}) = 5 \times 0.0007462 = 0.003731 \text{ mol}$$

$$\therefore n(\text{Fe}_2\text{O}_3) = 0.003731 / 2 = 0.0018655 \text{ mol}$$

$$\therefore m(\text{Fe}_2\text{O}_3) = 0.0018655 \times 159.688 = 0.297898 \text{ g}$$

In whole sample

$$\therefore m(\text{Fe}_2\text{O}_3) = 10 \times 0.297898 = 2.97898 \text{ g}$$

$$\therefore \text{percentage purity} = 2.97898 / 3.08 \times 100 = 96.7 \% \text{ pure}$$

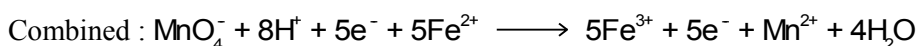
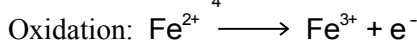
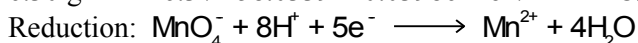
12.

1	2	3	4
FeO and Fe ₂ O ₃	Dissolved in sulfuric acid	Two equal aliquots	1. Titrated with 15.0 mL of 6.30 g L ⁻¹ KMnO ₄ 2. Reduced with zinc and Titrated with 25.1 mL of 6.30 g L ⁻¹ KMnO ₄

Zinc has the effect of reducing all the Fe³⁺ to Fe²⁺

Step 4

$$6.30 \text{ g L}^{-1} = 6.3 / 158.0339 = 0.03986 \text{ mol / L}^{-1} \text{ MnO}_4^-$$



$$\text{Mol Ratio } \text{MnO}_4^- : \text{Fe}^{2+} = 1:5$$

Titration 1

$$n(\text{MnO}_4^-) = c \times v = 0.03986 \times 0.0150 = 0.0005979 \text{ mol}$$

$$\therefore n(\text{Fe}^{2+}) = 5 \times 0.0005979 = 0.0029895 \text{ mol}$$

Titration 2

$$n(\text{MnO}_4^-) = c \times v = 0.03986 \times 0.0251 = 0.001000 \text{ mol}$$

$$\therefore n(\text{Fe}^{2+}) = 5 \times 0.001000 = 0.005002 \text{ mol}$$

$$\therefore n(\text{Fe}^{2+}) = n(\text{FeO}) = 0.002990 \text{ mol}$$

$$n(\text{Fe}^{3+}) = 2 \times n(\text{Fe}_2\text{O}_3) = 0.005002 - 0.002990 = 0.002013$$

$$\therefore n(\text{Fe}_2\text{O}_3) = \frac{1}{2} \times 0.002013 = 0.001006$$

For the half sample

$$\therefore m(\text{FeO}) = 0.002990 \times 71.844 = 0.2148 \text{ g}$$

$$\therefore m(\text{Fe}_2\text{O}_3) = 0.001006 \times 159.688 = 0.1607 \text{ g}$$

For the whole sample

$$\therefore m(\text{FeO}) = 0.2148 \times 2 = 0.4296 \text{ g}$$

$$\therefore m(\text{Fe}_2\text{O}_3) = 0.1607 \times 2 = 0.3214 \text{ g}$$

Set 32: Limiting reagents

1. a) 1 mole of Pb(NO₃)₂ requires 2 moles of KI
 0.300 mole of Pb(NO₃)₂: requires 2 x 0.300 = 0.600 mol of KI
 $n(\text{KI required}) > n(\text{KI available})$
 \therefore KI is LR
- b) $n(\text{PbI}_2) = \frac{1}{2} n(\text{KI})$
 $= \frac{1}{2} \times 0.400 = 0.200 \text{ mol}$
 $n(\text{PbI}_2) = 0.200 \times 461.0 = 92.2 \text{ g}$

Answers

2. a) $n(\text{NaOH}) = 5.55/39.998 = 0.139 \text{ mol}$
 $n(\text{HCl}) = 4.88/36.458 = 0.134 \text{ mol}$
 1 mol of NaOH requires 1 mol of HCl
 0.139 mol of NaOH requires
 0.139 mol of HCl
- $n(\text{HCl required}) > n(\text{HCl available})$
 HCl is LR
- b) $n(\text{NaCl}) = n(\text{HCl}) = 0.134 \text{ mol}$
 $m(\text{NaCl}) = 0.134 \times 58.44 = 7.82 \text{ g}$
3. a) $n(\text{CH}_3\text{COOH}) = 4.78/60.052 = 7.96 \times 10^{-2} \text{ mol}$
 $n(\text{CaCO}_3) = 2.22/100.08 = 2.22 \times 10^{-2} \text{ mol}$
 1 mole of CaCO_3 requires 2 moles of CH_3COOH
 $2.22 \times 10^{-2} \text{ mol}$ of CaCO_3 requires $2 \times (2.22 \times 10^{-2}) = 4.44 \times 10^{-2} \text{ mol}$ CH_3COOH
 $n(\text{CH}_3\text{COOH requ}) < n(\text{CH}_3\text{COOH avail})$
 $\therefore \text{CaCO}_3$ is LR
- b) $n(\text{CO}_2) = n(\text{CaCO}_3) = 2.22 \times 10^{-2} \text{ mol}$
 $m(\text{CO}_2) = (2.22 \times 10^{-2}) \times 44.01 = 0.976 \text{ g}$
- c) $n(\text{Ca}(\text{CH}_3\text{COO})_2) = n(\text{CaCO}_3) = 2.22 \times 10^{-2} \text{ mol}$
 $m(\text{Ca}(\text{CH}_3\text{COO})_2) = (2.22 \times 10^{-2}) \times 158.148 = 3.51 \text{ g}$
4. a) $n(\text{Mg}) = 6.08/24.3 = 0.250 \text{ mol}$
 $n(\text{H}_2\text{SO}_4) = 20.0/98.076 = 0.2039 \text{ mol}$
 1 mol of Mg requires 1 mol of H_2SO_4
 0.250 mol of Mg requires 0.250 mol of H_2SO_4
 $n(\text{H}_2\text{SO}_4 \text{ req}) > n(\text{H}_2\text{SO}_4 \text{ avail})$
 $\therefore \text{H}_2\text{SO}_4$ is LR
- b) $n(\text{H}_2) = n(\text{H}_2\text{SO}_4) = 0.2039 \text{ mol}$
 $m(\text{H}_2) = 0.2039 \times 2.016 = 0.411 \text{ g}$
- c) $n(\text{MgSO}_4 \cdot 7\text{H}_2\text{O}) = n(\text{H}_2\text{SO}_4) = 0.2039 \text{ mol}$
 $m(\text{MgSO}_4 \cdot 7\text{H}_2\text{O}) = 0.2039 \times 246.472 = 50.3 \text{ g}$
5. a) $n(\text{NaOH}) = 1.600/39.98 = 4.00 \times 10^{-2} \text{ mol}$
 $n(\text{H}_2\text{SO}_4) = 1.472/98.076 = 1.5 \times 10^{-2} \text{ mol}$
 1 mol of H_2SO_4 requires 2 mol of NaOH
 $1.5 \times 10^{-2} \text{ mol}$ of H_2SO_4 requires $2 \times (1.50 \times 10^{-2}) = 3.00 \times 10^{-2} \text{ mol}$
 $n(\text{NaOH req}) < n(\text{NaOH avail})$
 $\therefore \text{H}_2\text{SO}_4$ is LR
- b) $n(\text{Na}_2\text{SO}_4) = n(\text{H}_2\text{SO}_4) = 1.50 \times 10^{-2} \text{ mol}$
 $m(\text{Na}_2\text{SO}_4) = (1.50 \times 10^{-2}) \times 142.04 = 2.13 \text{ g}$
- c) $n(\text{NaOH rem}) = 4.00 \times 10^{-2} - 3.00 \times 10^{-2} = 1.00 \times 10^{-2} \text{ mol}$
 $m(\text{NaOH}) = (1.00 \times 10^{-2}) \times 39.998 = 0.400 \text{ g}$
6. a) $n(\text{Ag}) = 16.25/107.9 = 0.151 \text{ mol}$
 $n(\text{HNO}_3) = 18.4/63.018 = 0.292 \text{ mol}$
 1 mol of Ag requires $4/3$ mol of HNO_3
 0.151 mol of Ag requires $4/3 \times 0.151 = 0.201 \text{ mol}$
 $n(\text{HNO}_3 \text{ req}) < n(\text{HNO}_3 \text{ avail})$
 $\therefore \text{Ag}$ is LR
- b) $n(\text{NO}) = 1/3 n(\text{Ag}) = 1/3 \times 0.151 = 0.0503 \text{ mol}$
 $m(\text{NO}) = 0.0503 \times 30.01 = 1.51 \text{ g}$
- c) $n(\text{HNO}_3 \text{ rem}) = 0.292 - 0.201 = 0.091 \text{ mol}$
 $m(\text{HNCh}) = 0.091 \times 63.018 = 5.75 \text{ g}$
7. a) $n(\text{KO}_2) = 5.00/71.1 = 7.03 \times 10^{-2} \text{ mol}$
 $n(\text{CO}_2) = 9.00/44.01 = 0.204 \text{ mol}$
 1 mol of CO_2 requires 2 mol of KO_2
 0.204 mol requires $2 \times 0.204 = 0.408 \text{ mol}$ of KO_2
 $n(\text{KO}_2 \text{ required}) > n(\text{KO}_2 \text{ avail})$
 $\therefore \text{KO}_2$ is LR

Answers

$$n(\text{K}_2\text{CO}_3) = \frac{1}{2} n(\text{KO}_2) = \frac{1}{2} (7.03 \times 10^{-2}) = 3.52 \times 10^{-2} \text{ mol}$$

$$m(\text{K}_2\text{CO}_3) = (3.52 \times 10^{-2}) \times 138.21 = 4.86 \text{ g}$$

b) $n(\text{O}_2) = \frac{3}{2} n(\text{KO}_2) = \frac{3}{2} \times (7.03 \times 10^{-2}) = 0.105 \text{ mol}$

$$m(\text{O}_2) = 0.105 \times 32.00 = 3.36 \text{ g}$$

$$n(\text{CO}_2 \text{ rem}) = 0.204 - \frac{1}{2} (7.02 \times 10^{-2}) = 0.269 \text{ mol}$$

$$m(\text{CO}_2) = 0.269 \times 44.01 = 7.43 \text{ g}$$

8. $n(\text{Ca}_3(\text{PO}_4)_2) = 25.0 \times 10^6 / 310.18 = 8.06 \times 10^4 \text{ mol}$

$$N(\text{H}_3\text{PO}_4) = 30.0 \times 10^6 / 97.94 = 3.06 \times 10^5 \text{ mol}$$

1 mol of $\text{Ca}_3(\text{PO}_4)_2$ requires 4 mol of H_3PO_4

$$8.06 \times 10^4 \text{ mol of } \text{Ca}_3(\text{PO}_4)_2 \text{ requires } 4 \times (8.06 \times 10^4) = 3.224 \times 10^5 \text{ mol of } \text{H}_3\text{PO}_4$$

$$n(\text{H}_3\text{PO}_4 \text{ req}) > n(\text{H}_3\text{PO}_4 \text{ avail})$$

$\therefore \text{H}_3\text{PO}_4$ is LR

$$n(\text{Ca}(\text{H}_2\text{PO}_4)_2) = \frac{3}{4} (n(\text{H}_3\text{PO}_4 \text{ avail})) = \frac{3}{4} (3.06 \times 10^5) = 2.296 \times 10^5 \text{ mol}$$

$$m(\text{Ca}(\text{H}_2\text{PO}_4)_2) = (2.296 \times 10^5) \times 234.052 = 5.37 \times 10^7 \text{ g (53.7 tonne)}$$

9. $n(\text{CO}_2) = 2.94/44.01 = 6.68 \times 10^{-2} \text{ mol}$

$$n(\text{Na}_2\text{CO}_3) = n(\text{CO}_2) = 6.68 \times 10^{-2} \text{ mol}$$

$$m(\text{Na}_2\text{CO}_3) = (6.68 \times 10^{-2}) \times 105.99 = 7.08 \text{ g}$$

$$\% \text{Na}_2\text{CO}_3 := 7.08/7.20 \times 100 = 98.3\%$$

10. $n(\text{Cl}_2) = 2.84/70.9 = 4.01 \times 10^{-2} \text{ mol}$

$$\text{mol } n(\text{MnO}_2) = n(\text{Cl}_2) = 4.01 \times 10^{-2} \text{ mol}$$

$$m(\text{MnO}_2) = (4.01 \times 10^{-2}) \times 86.94 = 2.49 \text{ g}$$

$$\% \text{MnO}_2 = 2.49/3.52 \times 100 = 99.0\%$$

Set 33: Calculations involving gases

1. a

P	V	n	R	T
120.1	0.45		8.314	299

$n = 0.0217 \text{ mol}$

b

P	V	n	R	T
99.3	0.889		8.314	314.15

$n = 0.0338 \text{ mol}$

c

P	V	n	R	T
145	27.5		8.314	328.15

$n = 1.462 \text{ mol}$

2.(a)

P	V	n	R	T	Mass
105	0.59		8.314	298.15	2.22

$n = 0.023678613 \text{ mol}$
 If $0.023678613 \text{ mol} = 2.22 \text{ g}$
 Then $1 \text{ mol} = 93.8 \text{ g}$

(b)

P	V	n	R	T	Mass
98.5	1.22		8.314	348.15	0.456

$n = 0.041516396 \text{ mol}$
 If $0.041516396 \text{ mol} = 0.456 \text{ g}$
 Then $1 \text{ mol} = 11.0 \text{ g}$

(c)

P	V	n	R	T	Mass
68.4	3.33		8.314	393.15	6.46

$n = 0.069683834 \text{ mol}$
 If $0.069683834 \text{ mol} = 6.46 \text{ g}$
 Then $1 \text{ mol} = 92.7 \text{ g}$

Answers

4. $P \quad V \quad n \quad R \quad T$
 105 0.0255 8.314 298.15
 $n = 0.001080151 \text{ mol of CO}_2$
 \therefore there were 0.001080151 mol of CaCO_3
 $= 100 \times 0.001080151 = 0.108 \text{ g CaCO}_3$
5. $2\text{NH}_3(\text{g}) + \text{H}_2\text{SO}_4(\text{aq}) \longrightarrow (\text{NH}_4)_2\text{SO}_4$
 $n\text{NH}_3 = 1.50 / 22.71 = 0.06605 \text{ mol}$
 $n\text{H}_2\text{SO}_4 = c \times V = 2.54 \times 0.050 = 0.127 \text{ mol}$
 (a) To use all the NH_3 we need $1/2$ that number of moles of $\text{H}_2\text{SO}_4 = 1/2 \times 0.06605 = 0.03303 \text{ mol acid}$ needed and have 0.127 mol – so acid is in excess and the LR is NH_3
 (b) $n(\text{NH}_4)_2\text{SO}_4 \text{ produced} = 1/2 n(\text{NH}_3 \text{ used}) = 1/2 (0.06605) = 0.03303 \text{ moles:}$
 mass ammonium sulfate = $M \times n = 132.094 \times 0.03303 = 4.36 \text{ g}$
 (c) $n\text{H}_2\text{SO}_4 \text{ left over} = 0.127 \text{ available} - 0.03303 \text{ used} = 0.09397 \text{ mol in excess}$
6. $\text{NaHCO}_3 + \text{HCl} \longrightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{NaCl}$
 $n\text{NaHCO}_3 = 0.273 / 84.00 = 0.0032497 \text{ mol}$
 $n\text{HCl} = c \times V = 2.50 \times 0.050 = 0.125 \text{ mol}$
 (a) $\therefore \text{NaHCO}_3$ is the LR
 (b) $n(\text{CO}_2) = n(\text{NaHCO}_3): V(\text{CO}_2) = nRT / P = 0.085 \text{ L}$
7. $\text{Cu} + 4\text{HNO}_3 \longrightarrow \text{Cu}(\text{NO}_3)_2 + 2\text{NO}_2 + 2\text{H}_2\text{O}$
 $n\text{Cu} = 1.33 / 63.55 = 0.0208 \text{ mol}$
 $n\text{HNO}_3 = c \times V = 6.00 \times 0.025 = 0.15 \text{ mol}$
 (a) To use all the Cu we need $0.0208 \times 4 \text{ mol HNO}_3 = 0.0832 \text{ mol}$
 We have more so the Cu is the LR
 (b) $\therefore n\text{NO}_2 = 2 \times 0.0208 = 0.0416 \text{ mol}$
 $V = 1.02 \text{ L}$
8. $\text{MnO}_2 + 4\text{H}^+ + 2\text{Cl}^- \longrightarrow \text{Mn}^{2+} + \text{Cl}_2 + 2\text{H}_2\text{O}$
 Or: $\text{MnO}_2 + 4\text{HCl} \rightarrow \text{MnCl}_2 + \text{Cl}_2 + 2\text{H}_2\text{O}$
 $n\text{MnO}_2 = 3.44 / 86.93 = 0.0396 \text{ mol}$
 $n\text{HCl} = 6.20 \times 0.150 = 0.093 \text{ mol}$
 $n\text{HCl needed} = n\text{H}^+ \text{ used} = 4 \times n\text{MnO}_2 = 0.158 \text{ mol}$
 You need more HCl than you have so HCl is the limiting reagent
 $\therefore n\text{Cl}_2 = 1/4 \text{ HCl} = 1/4(0.093) = 0.02325 \text{ mol}$
 $P = nRT / V = 238.26 \text{ kPa} = 238 \text{ kPa}$
9. $(\text{NH}_4)_2\text{SO}_4 + 2\text{KNO}_3 \longrightarrow \text{K}_2\text{SO}_4 + 4\text{H}_2\text{O} + 2\text{N}_2$
 $n(\text{NH}_4)_2\text{SO}_4 = 30.0 / 132.140 = 0.227031 \text{ mol}$
 $n\text{KNO}_3 = 34.0 / 101.1032 = 0.33629 \text{ mol}$
 To use all the $(\text{NH}_4)_2\text{SO}_4$ we would need $2 \times 0.22703 \text{ mol KNO}_3 = 0.45406 \text{ mol}$
 (a) KNO_3 is the LR and is used up.
 (b) $n(\text{NH}_4)_2\text{SO}_4 \text{ used} = 1/2 n\text{KNO}_3 = 0.16814 \text{ mol: } n(\text{NH}_4)_2\text{SO}_4$
 left over = $0.22701 - 0.16814 = 0.05887 \text{ mol is INXS}$
 $m = n \times M = 0.058886 \times 132.140 = 7.78 \text{ g}$
 (c) $n\text{N}_2 = n\text{KNO}_3 : P = nRT / V = 1814 \text{ kPa}$

Set 34: Empirical formulas 1

1. (a)
- | | Fe | Cl |
|-------------------------------|--------|--------|
| m | 2.76 | 3.51 |
| n | 2.76 | 3.51 |
| | 55.85 | 35.45 |
| | 0.0494 | 0.0990 |
| Ratio (\div - by smallest) | 0.0494 | 0.990 |
| | 0.0494 | 0.494 |
| | 1 | 2 |
- E.F. = FeCl₂**
- (b)
- | | C | H |
|-----------------------------|-------|-------|
| m | 2.06 | 0.430 |
| n | 2.06 | 0.430 |
| | 12.01 | 1.008 |
| | 0.172 | 0.427 |
| Ratio (\div by smallest) | 0.172 | 0.427 |
| | 0.172 | 0.172 |
| | 2 | 5 |
- EF C₂H₅**
- (c)
- | | K | Mn | O |
|-----------------------------|-----------------------|-----------------------|-----------------------|
| m | 3.71 | 5.21 | 6.07 |
| | 3.71 | 5.21 | 6.07 |
| | 39.1 | 54.94 | 16.00 |
| | 9.49×10^{-2} | 9.48×10^{-2} | 0.379 |
| Ratio (\div by smallest) | 9.49×10^{-2} | 9.48×10^{-2} | 0.379 |
| | 9.48×10^{-2} | 9.48×10^{-2} | 9.48×10^{-2} |
- E.F. = KMnO₄**
- (d)
- | | Na | S | O |
|-----------------------------|-------|-------|--------|
| m | 3.86 | 5.38 | 10.7 |
| n | 3.86 | 5.38 | 10.7 |
| | 22.99 | 32.06 | 16.00 |
| | 0.168 | 0.168 | 0.6688 |
| Ratio (\div by smallest) | 1.68 | 0.168 | 0.6688 |
| | 0.168 | 0.168 | 0.168 |
| | 1 | 1 | 4 |
- E.F. = NaSO₄**
2. (a)
- | | Ca | O | H |
|-----------------------------|-------|-------|-------|
| | 54.1 | 43.2 | 2.70 |
| | 54.1 | 43.2 | 2.70 |
| | 40.08 | 16.00 | 1.008 |
| | 1.35 | 2.70 | 2.68 |
| Ratio (\div by smallest) | 1.35 | 2.70 | 2.68 |
| | 1.35 | 1.35 | 1.35 |
| | 1 | 2 | 2 |
- E.F. = CaO₂H₂ (Ca(OH)₂)**

Answers

(b)

	Pb	N	O
m in 100 g	62.5	8.50	29.0
n	62.5	8.50	29.0
	207.2	14.01	16.00
	0.302	0.607	1.812
Ratio (\div by smallest)	0.302	0.607	1.812
	0.302	0.302	0.302
	1	2	6

E.F. = $\text{PbN}_2\text{O}_6, (\text{Pb}(\text{NO}_3)_2)$

(c)

	C	O	H
m in 100 g	60.0	26.7	13.3
n	60.0	26.7	13.3
	12.01	16.00	1.008
	5.00	1.669	13.2
Ratio (\div by smallest)	5.00	1.669	13.2
	1.669	1.669	1.669
	3	1	8

E.F. = $\text{C}_3\text{H}_8\text{O}$

3.

	S	O
m in 100 g	40.0	60.0
n	40.0	60.0
	32.06	16.00
	1.25	3.75
Ratio (\div by smallest)	1.25	3.75
	1.25	1.25
	1	3

E.F. = SO_3

4. %C = $1.25/2.12 \times 100 = 58.96\%$
 %H = $0.161/1.64 \times 100 = 9.82\%$
 %O = $100 - (58.96 + 9.82) = 31.22\%$

	C	O	H
m in 100 g	58.96	31.22	9.82
n	58.96	31.22	9.82
	12.01	16.00	1.008
	4.91	1.95	9.74
Ratio (\div by smallest)	4.91	1.95	9.74
	1.95	1.95	1.95
	2.5	1	5
x2	5	2	10

E.F. = $\text{C}_5\text{H}_{10}\text{O}_2$

5.

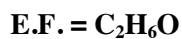
	Te	O
m	4.00	1.00
n	4.00	1.00
	127.6	16.00
	3.13×10^{-2}	6.25×10^{-2}
Ratio (\div by smallest)	3.13×10^{-2}	6.25×10^{-2}
	3.13×10^{-2}	3.13×10^{-2}
	1	2

E.F. = TeO_2

Answers

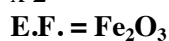
6. $\%O = (52.0 + 13.0) = 35.0\%$

	C	O	H
m in 100 g	52.0	35.0	13.0
n	52.0	35.0	13.0
	12.01	16.00	1.008
	4.33	2.19	12.9
Ratio (\div by smallest)	4.33	2.19	12.9
	2.19	2.19	2.19
	2	1	6



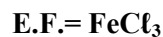
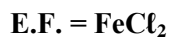
7.

	Fe	O
m	7.83	11.2-7.83 = 3.37
n	47.83	3.37
	55.85	16.00
	0.140	0.211
Ratio (\div by smallest)	0.140	0.211
	0.140	0.140
x 2	2	3



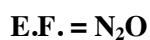
8.

	Fe	Cl	Fe	Cl
m	44.0	100-44.0 = 56	34.4	100-34.4 = 65.6
n	44.0	56.5	34.4	65.6
	55.85	35.45	55.85	35.45
	0.788	1.58	0.616	1.85
Ratio (\div by smallest)	0.788	1.58	0.616	1.85
	0.788	1.58	0.616	0.616
	1	2	1	3

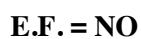


9.

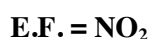
	N	O
m in 100 g	63.6	36.4
n	63.6	36.4
	14.01	16.00
	4.54	2.275
Ratio (\div by smallest)	4.54	2.275
	2.275	2.275
	2	1



	N	O
m in 100 g	46.7	53.3
n	46.7	53.3
	14.01	16.00
	3.33	3.33
Ratio (\div by smallest)	3.33	3.33
	3.33	3.33
	1	3.33



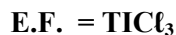
	N	O
m in 100 g	30.4	69.6
n	30.4	69.6
	14.01	16.00
	2.17	4.35
Ratio (\div by smallest)	2.17	4.35
	2.17	2.17
	1	2



Answers

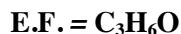
10. $n(\text{Cl}^-) = n(\text{AgCl}) = 9.47 / 143.35 = 6.61 \times 10^{-2} \text{ mol}$
 $m(\text{Cl}^-) = (6.61 \times 10^{-2}) \times 35.45 = 2.34 \text{ g}$

	Ti	Cl
m	$3.40 - 2.34 = 1.06$	2.34
n	1.06	2.34
	47.88	35.45
	2.21×10^{-2}	6.61×10^{-2}
Ratio (\div by smallest)	2.21×10^{-2}	6.61×10^{-2}
	2.21×10^{-2}	2.21×10^{-2}
	1	3



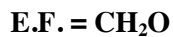
11. $n(\text{CO}_2) = 0.660 / 12.01 = 1.50 \times 10^{-2} \text{ mol}$
 $n(\text{H}_2\text{O}) = 0.270 / 18.016 = 1.50 \times 10^{-2} \text{ mol}$
 $n(\text{C}) = n(\text{CO}_2)$
 $m(\text{CO}_2) = 12.01 \times 1.50 \times 10^{-2} = 0.180 \text{ g}$
 $n(\text{H}) = 2n(\text{H}_2\text{O})$
 $m(\text{H}_2) = 2 \times 1.008 \times 1.50 \times 10^{-2} = 0.0302 \text{ g}$
 $m(\text{O}) = 0.290 - (0.180 + 0.0302) = 0.0798 \text{ g}$
 $n(\text{O}) = 0.0798 / 16.00 = 4.99 \times 10^{-3} \text{ mol}$

	C	H	O
n	1.50×10^{-2}	3.00×10^{-2}	4.99×10^{-3}
Ratio	1.50×10^{-2}	3.00×10^{-2}	4.99×10^{-3}
	4.99×10^{-3}	4.99×10^{-3}	4.99×10^{-3}
	3	6	1



12. $n(\text{CO}_2) = 0.403 / 12.01 = 9.16 \times 10^{-3} \text{ mol}$
 $n(\text{C}) = n(\text{CO}_2)$
 $m(\text{C}) = 12.01 \times 9.16 \times 10^{-3} = 0.110 \text{ g}$
 $n(\text{H}_2\text{O}) = 0.165 / 18.016 = 9.16 \times 10^{-3} \text{ mol}$
 $n(\text{H}) = 2n(\text{H}_2\text{O})$
 $m(\text{H}) = 2 \times 1.008 \times (9.16 \times 10^{-3}) = 0.0185 \text{ g}$

	C	H	O
n	9.16×10^{-3}	1.83×10^{-2}	9.16×10^{-3}
Ratio	9.16×10^{-3}	1.83×10^{-2}	9.16×10^{-3}
	9.16×10^{-3}	4.99×10^{-3}	4.99×10^{-3}
	1	2	1



13. $n(\text{CO}_2) = 1.600 / 12.01 = 3.64 \times 10^{-2} \text{ mol}$
 $n(\text{C}) = n(\text{CO}_2)$
 $m(\text{C}) = 12.01 \times (3.64 \times 10^{-2}) = 0.437 \text{ g}$
 $n(\text{H}_2\text{O}) = 0.770 / 18.016 = 4.274 \times 10^{-2} \text{ mol}$
 $n(\text{H}) = 2n(\text{H}_2\text{O}) =$
 $m(\text{H}) = 2 \times 1.008 \times (4.274 \times 10^{-2}) = 0.0862 \text{ g}$
 $n(\text{N}) = 0.1697 / 14.01 = 1.21 \times 10^{-2}$
 $m(\text{O}) = 1.279 - (0.437 + 0.0862 + 0.1697) = 0.586$
 $n(\text{O}) = 0.586 / 16.00 = 3.66 \times 10^{-2} \text{ mol}$

	C	H	O	N
N	3.64×10^{-2}	8.62×10^{-2}	3.66×10^{-2}	1.21×10^{-2}
Ratio	3.64×10^{-2}	8.62×10^{-2}	3.66×10^{-2}	1.21×10^{-2}
	1.21×10^{-2}	1.21×10^{-2}	1.21×10^{-2}	1.21×10^{-2}
	3	7	3	1



Set 35: Empirical formulas 2

1. $n(\text{CO}_2) = 0.531/44.01 = 1.21 \times 10^{-2} \text{ mol} = n(\text{CO}_3^{2-})$
 $m(\text{CO}_3^{2-}) = 60.01 \times (1.21 \times 10^{-2}) = 0.724 \text{ g}$
 $n(\text{H}_2\text{O}) = 0.219 / 18.016 = 1.21 \times 10^{-2} \text{ mol} = n(\text{OH}^-)$
 $m(\text{OH}^-) = (1.21 \times 10^{-2}) \times 17.008 = 0.2067 \text{ g}$
 $m(\text{Cu}) = 2.088 - (0.724 + 0.2067) = 1.157 \text{ g}$
 $n(\text{Cu}) = 1.157 / 63.55 = 1.82 \times 10^{-2} \text{ mol}$

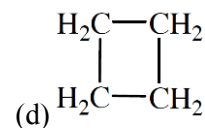
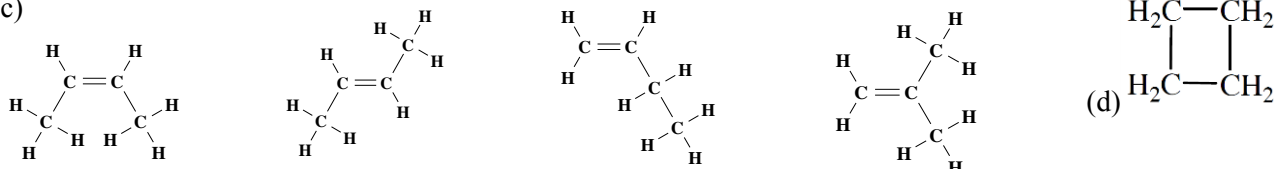
	Cu	CO_3^{2-}	OH
<i>n</i>	1.82×10^{-2}	1.21×10^{-2}	1.21×10^{-2}
Ratio	1.82×10^{-2}	1.21×10^{-2}	1.21×10^{-2}
	1.21×10^{-2}	1.21×10^{-2}	1.21×10^{-2}
	1.5	1	1
x 2	3	2	2
E.F. = $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$			

2. (a)
- | | C | H |
|------------|--------------|---------|
| m in 100 g | 85.7 | 14.3 |
| n | 85.7 | 143 |
| | 12.01 | 1.008 |
| | = 7.14 | = 14.18 |
| Ratio | 7.14 | 14.18 |
| | 7.14 | 7.14 |
| | 1 | 2 |

E.F. = CH_2

- (b)
 $n = 1.18 \times 10^5 / 298 \times 8.315 = 5.00 \times 10^2 \text{ mol}$
 $M = 2.80 / 5.00 \times 10^{-2} = 56.00 \text{ g mol}^{-1}$
 $\text{MF} = 56 / 14.00 = 4$
 $\text{MF} = \text{C}_4\text{H}_8$

(c)



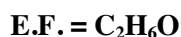
3. $\% \text{Pb} = 2.93 / 3.41 \times 100 = 85.9 \%$
 $n(\text{AgCl}) = 1.16 / (107.9 + 35.45) = 8.09 \times 10^{-3} \text{ mol} = n(\text{Cl}^-)$
 $M(\text{Cl}^-) = (8.09 \times 10^{-3}) \times 35.45 = 0.287 \text{ g}$
 $\% \text{Cl} = 0.287 / 2.93 \times 100 = 9.79 \%$
 $\% \text{O} = 100 - (85.9 + 9.79) = 4.31 \%$

	Pb	Cl	O
M in 100 g	859	9.79	431
N	85.9	9.79	4.31
	207.2	35.45	16.00
	= 0.415 mol	= 0.276 mol	= 0.269
ratio	0.415	0.276	1
	0.269	0.269	1
	= 1.5	= 1	1

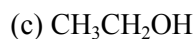
E.F. = $\text{Pb}_3\text{Cl}_2\text{O}_2$

4. (a)
 $n(\text{CO}_2) = 6.60 / 44.01 = 0.150 \text{ mol} = n(\text{C})$
 $m(\text{C}) = 0.150 \times 12.01 = 1.80 \text{ g}$
 $n(\text{H}_2\text{O}) = 4.05 / 18.016 = 0.224 \text{ mol}$
 $n(\text{H}) = 2 \times 0.224 = 0.450 \text{ mol}$
 $m(\text{H}) = 0.450 \times 1.008 = 0.453 \text{ g}$
 $m(\text{O}) = 3.45 - (1.80 + 0.453) = 1.197 \text{ g}$
 $n(\text{O}) = 1.197 / 16.0 = 0.0750 \text{ mol}$

	C	H	O
n	0.150	0.450	0.0750
ratio	0.150	0.450	0.0750
	0.0750	0.0750	0.0750
	2	6	1

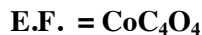


- (b)
 $n = 0.950 \times 98 / 373 \times 8.315 = 3.00 \times 10^{-2} \text{ mol}$
 $M = 1.38 / 3.00 \times 10^{-2} = 46.0 \text{ g mol}^{-1}$
 EFM=MFM
MF = C₂H₆O



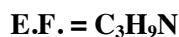
5. (a)
 $n(\text{CoCO}_3) = 0.849 / (58.93 + 12.01 + 48.00) = 7.14 \times 10^{-3} \text{ mol}$
 $M(\text{Co}) = (7.14 \times 10^{-3}) \times 58.93 = 0.421 \text{ g}$
 $\% \text{Co} = 0.421 / 1.22 \times 100 = 34.5 \%$
 $n(\text{C}) = 3.43 / 44.01 = 7.79 \times 10^{-3} \text{ mol}$
 $M(\text{C}) = (7.79 \times 10^{-3}) \times 12.01 = 0.936 \text{ g}$
 $\% \text{C} = 0.936 / 3.33 \times 100 = 28.1 \%$
 $\% \text{O} = 100 - (34.5 + 28.1) = 37.4 \%$

	Co	C	O
M in 100 g	34.5	28.1	37.4
N	34.5	28.1	37.4
	58.93	12.01	16.00
	= 0.585 mol	= 2.34 mol	= 2.34 mol
Ratio	1	234	234
		0.585	0.585
	1	4	4



- (b)
 EFM = 58.93 + (4 × 12.01) + (4 × 16.00) = 170.93
 Ratio = 341.9 / 170.93 = 2
 MF = 2 × EF = Co₂C₈O₈

6. (a)
- | | C | C | N |
|-------|---------------------------|-------------------------|-----------------------------|
| n | 2.64 | 1.62 × 2 | 0.236 × 10 ⁵ × 2 |
| | 44.01 | 18.016 | 298 × 8.315 |
| n | = 6.00 × 10 ⁻² | = 0.1798 | = 2.00 × 10 ⁻² |
| ratio | 6.00 × 10 ⁻² | 0.1798 | 1 |
| | 2.00 × 10 ⁻² | 2.00 × 10 ⁻² | |
| | 3 | 9 | |



Answers

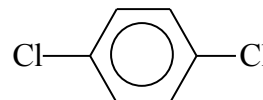
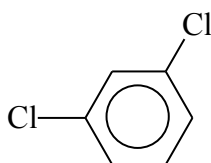
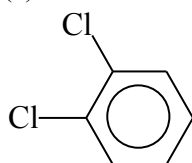
(b)
 $n = 0.254 \times 95.5 / (19 + 273) \times 8.315 = 9.99 \times 10^{-3} \text{ mol}$
 $M = 0.5896 / 9.99 \times 10^{-3} = 59.0 \text{ g}$
 $\text{EFM} = (3 \times 12.01) + (9 \times 1.008) + 14.01 = 59.1 \text{ g}$
 $\text{EFM} = \text{MFM}$
 $\text{MF} = \text{C}_3\text{H}_9\text{N}$

7.	(a)	C	Cl	H
		1.189×12.01	1.292×35.45	$0.662 - (0.3245 + 0.3195)$
		44.01	143.35	
		= 0.3245 g	= 0.3195 g	= 0.0180 g
	n	0.3245	0.3195	0.0180
		12.01	35.45	1.008
		= 0.0271 mol	= 9.01×10^{-3} mol	= 0.0179 mol
	Ratio	0.0271	1	0.0179
		9.01×10^{-3}		9.01×10^{-3}
		= 3	= 1	= 2

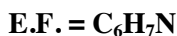


(b) $\text{EFM} = (3 \times 12.01) + (2 \times 1.008) + 35.45 = 73.5$
 $\text{Ratio} = 147 / 73.5 = 2$
 $\text{MF} = 2 \times \text{EF} = \text{C}_6\text{H}_4\text{Cl}_2$

(c)



8.	C	H	N
	1.76×12.01	$0.420 \times 2 \times 1.008$	$0.0295 \times 101.3 \times 2 \times 14.1$
	44.01	18.016	$(15 + 273) \times 8.315$
	= 0.480g	= 0.0470g	= 0.0350g
%	0.480×100	0.0470	0.0350
(m in 100 g)	0.620	0.620	0.232
	= 77.4%	= 7.58%	= 15.1%
n	77.29	7.52	15.1
	12.01	1.008	14.01
	= 6.44	= 7.52	= 1.08
ratio	6.44	7.52	1
	1.08	1.08	
	= 6	= 7	= 1



(b) $n = 100 \times 101.3 / (100 + 273) \times 8.315 = 3.27 \times 10^{-2} \text{ mol}$

$M = 3.04 / 3.27 \times 10^{-2} = 93.1 \text{ g mol}^{-1}$
 $\text{EFM} = (6 \times 12.01) + (7 \times 1.008) + 14.01 = 93$
 $\text{MF} = \text{EF} = \text{C}_6\text{H}_7\text{N}$

Answers

9. $\%H_2O = (5.43 - 4.88) / 5.43 \times 100 = 10.4\%$
 $m(Ni) = 0.578 / (58.69 + 32.06) \times 58.69 = 0.374 \text{ g}$
 $\%Ni = 0.374 / ((2.00/4.88) \times 5.43) \times 100 = 16.8\%$
 $\%C_2O_4 = 50.5\%$
 $\%K = 100 - (10.4 + 16.8 + 50.5) = 22.3 \%$

	K	Ni	C ₂ O ₄	H ₂ O
%	22.3	16.8	50.5	10.4
(m in 100g)				
n	22.3	16.8	50.5	10.4
	39.1	58.69	88.02	18.016
	= 0.570mol	= 0.286mol	0.574mol	0.577mol
ratio	0.570	1	0.574	0.577
	0.286		0.286	0.286
	=2	=1	=2	=2



10. $n(BaSO_4) = 0.4671 / (137.3 + 32.06 + 64.00) = 2.00 \times 10^{-3} \text{ mol} = n(S)$
 $m(S) = (2.00 \times 10^{-3}) \times 32.06 = 6.42 \times 10^{-2} \text{ g}$
 $n(OH^-) = 0.250 \times 0.024 = 6.00 \times 10^{-3} \text{ mol}$
 $n(HCl) = n(NaOH) - 2n(H_2SO_4)$
 $n(Cl^-) = n(OH^-) - 2n(S) = 6.00 \times 10^{-3} - 4.00 \times 10^{-3} = 2.00 \times 10^{-3} \text{ mol}$
 $m(Cl^-) = 35.45 \times (2.00 \times 10^{-3}) = 0.0709 \text{ g}$

	S	Cl	O
%	$6.42 \times 10^{-2} \times 100$	0.0709×100	$100 - (23.7 + 26.2)$
(m in 100 g)	0.2702	0.2702	
	= 23.7%	= 26.2 %	= 50.1 %
n	23.7	26.2	50.1
	32.06	35.45	16.00
ratio	= 0.739 mol	= 0.739 mol	= 3.13/0.739 mol
	1	1	4.25
	1	1	3.13/ 0.739
	1	1	4.25
x4	4	4	17



Set 36: Chemical Synthesis: no answers provided