SYDNEY GRAMMAR SCHOOL

2015
FORM VI
TRIAL HSC EXAMINATION

Chemistry

Thursday 30th July 8:40 a.m.

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Board-approved calculators may be used
- Write using blue or black pen
- Draw diagrams using pencil
- A Data Sheet and Periodic Table are provided at the back of this paper
- Write your candidate number and master's initials at the top of each page in Part B **and on the Answer Booklets**

CHECKLIST	
Each boy should have the following :	
1 Question Paper	
1 Multiple Choice Answer Sheet	
2 Five Page Booklets	

Section I Pages 3 - 20

Total marks (100)

This section has two parts, Part A and Part B

Part A
Total marks **(20)**
- Attempt Questions 1-20
- Allow about 30 minutes for this Section

Part B
Total marks **(55)**
- Attempt Questions 21-36
- Allow about 1 hour and 45 minutes for this Section

Section II Pages 21-25
Total marks **(25)**
- Attempt Question 37 in this section.
- Allow about 45 minutes for this Section

Chemistry Classes:

1. TW	2. CRMR	3. AKBB	
4. EJS	5. MRB	6. MTK	

EXAMINERS: TW / AKBB / MTK / MRB

Part A

Total marks (20)
Attempt Questions 1-20
Allow about 30 minutes for this Part

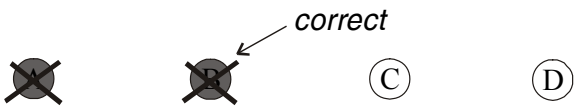
Use the multiple-choice Answer Sheet.

Select the alternative A, B, C or D that best answers the question. Fill the response circle completely.

Sample 2 + 4 =

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

If you change your mind and have crossed out what you consider to be the correct answer, then indicate this by writing the word *correct* and drawing an arrow as follows.



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1 Which of the following isotopes is radioactive?

(A) $^{13}_{5}B$

(B) $^{59}_{27}Co$

(C) $^{31}_{15}P$

(D) $^{200}_{80}Hg$

2 Which of the following statements is true about unstable isotopes?

(A) They all have an atomic number greater than 82.
(B) They all have an atomic number greater than 92.
(C) They all have more neutrons than protons.
(D) They all decay emitting a small particle or energy.

3 Given the following half equation and $E^{\ominus}$ value:

$O_{2(g)} + 2H^{+}_{(aq)} + 2e^{-} \rightarrow H_2O_{2(aq)}$ $\quad E^{\ominus} = +0.70$ V

What is the voltage produced under standard conditions for the following reaction?

$2MnO_4^{-}(aq) + 5H_2O_2(aq) + 6H^{+}(aq) \rightarrow 2Mn^{2+}(aq) + 5O_2(g) + 8H_2O(l)$

(A) 0.70 V
(B) 0.81 V
(C) 1.51 V
(D) 2.21 V

4 Reactions of metals in dilute acids can be described as redox reactions for which of the following reasons?

(A) There is a transfer of electrons from the hydrogen ions to the metal.
(B) There is a transfer of electrons from the metal to the hydrogen ions.
(C) There is a transfer of electrons from the anions to the cations.
(D) There is a transfer of electrons from the cations to the anions.

5 Which of the following is true about ethanol?

(A) It has the formula CH_3COOH.
(B) It can act as a solvent of both polar and non-polar substances.
(C) It is the smallest possible alkanol.
(D) It is the monomer from which cellulose is produced.

6 What is the defining principle common to all condensation polymerisations?

(A) They all produce water.
(B) They are all formed by reactions across double bonds.
(C) They all involve the addition of small molecules.
(D) They all involve the ejection of small molecules.

7 What is the major industrial source of ethylene?

(A) Dehydration of ethanol.
(B) Cracking of petroleum
(C) Fermentation of sugars
(D) Lysis of polyethylene

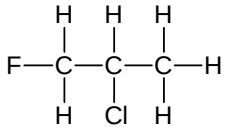
8 How many isomers are there for C_2H_3BrClF?

(A) 2
(B) 3
(C) 4
(D) 5

9 Waste water from a factory is contaminated with a significant concentration of dissolved calcium ions. Which of the following ions could also be dissolved at the highest concentration in the waste water?

(A) chloride
(B) carbonate
(C) phosphate
(D) sulfate

10 What is the correct IUPAC name for the following compound?

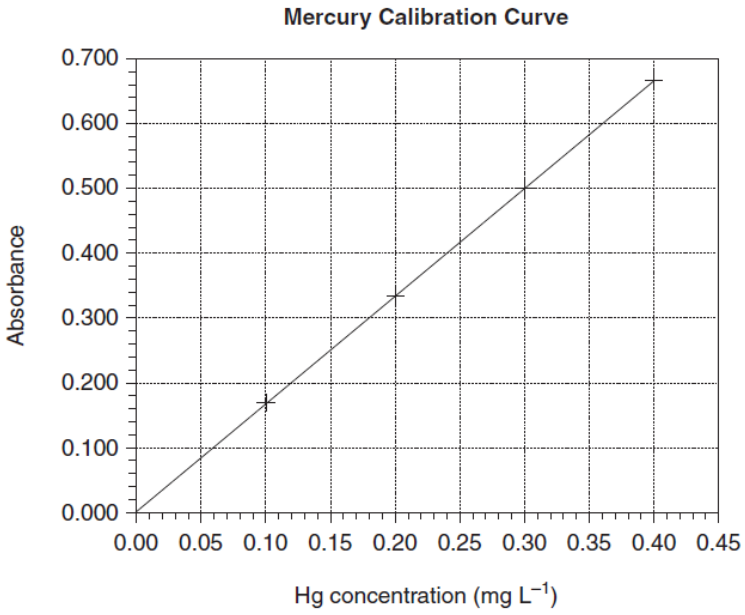


(A) 2-chloro-1-fluoropropane
(B) 1-fluoro-2-chloropropane
(C) 2-chloro-3-fluoropropane
(D) 3-fluoro-2-chloropropane

11 Which of the following is a balanced chemical equation representing the incomplete combustion of an alkane?

(A) $C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(l)}$
(B) $C_2H_5OH_{(l)} + 2O_{2(g)} \rightarrow CO_{(g)} + C_{(s)} + 3H_2O_{(l)}$
(C) $C_2H_{4(g)} + 2O_{2(g)} \rightarrow 2CO_{(g)} + 2H_2O_{(l)}$
(D) $C_4H_{10(g)} + 5O_{2(g)} \rightarrow CO_{2(g)} + 3CO_{(g)} + 5H_2O_{(l)}$

12 Below is a calibration curve generated when using an atomic absorption spectrometer (AAS) to detect mercury.



A 500 mL sample of unknown mercury concentration gives an absorbance of 0.500 on the same instrument.

What is the concentration of mercury in the unknown sample?

(A) 3.00×10^{-1} M
(B) 1.50×10^{-2} M
(C) 1.50×10^{-3} M
(D) 1.50×10^{-6} M

13 All the strontium ions present in a 250 mL solution were precipitated by reaction with excess sulfate ions. The mass of the dried strontium sulfate obtained after filtration, washing and drying was 0.353 g.

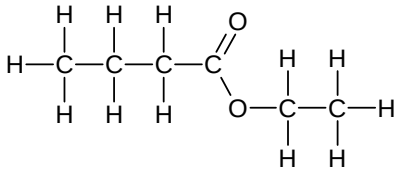
What was the concentration of strontium ions in the original solution?

(A) 168 mg L^{-1}
(B) 477 mg L^{-1}
(C) 673 mg L^{-1}
(D) 1412 mg L^{-1}

14 Which of the following indicators would best identify the equivalence point of the titration of 0.1 M ammonia with 0.1 M hydrochloric acid?

(A) methyl orange
(B) phenolphthalein
(C) bromothymol blue
(D) litmus

15 The structural formula of an ester with a strawberry fragrance is shown below:



Which alkanoic acid and alkanol could be used to synthesise this ester?

	alkanol	alkanoic acid
(A)	ethanol	propanoic acid
(B)	ethanol	butanoic acid
(C)	1-butanol	ethanoic acid
(D)	1-propanol	ethanoic acid

16 Which equation below best represents hydrogen chloride gas acting as a Brønsted-Lowry acid?

(A) $HCl(g) \xrightarrow{H_2O} HCl(aq)$
(B) $HCl(g) \xrightarrow{H_2O} H^+(aq) + Cl^-(aq)$
(C) $HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$
(D) $2HCl(g) + Sn(s) \rightarrow H_2(g) + SnCl_2(s)$

17 Which of the following solutions contains the highest molar concentration of acid?

(A) An acetic acid solution with a pH of 3.
(B) A hydrochloric acid solution with a pH of 3.
(C) A sulfuric acid solution with a pH of 3.
(D) A citric acid solution with a pH of 3.

18 Two drops (0.1 mL) of 0.01 M HCl solution is added to 10 mL of a HCl solution with a pH of 5. The pH of the resulting solution will be closest to:

(A) 3
(B) 4
(C) 5
(D) 6

19 Two drops (0.1 mL) of 0.01 M HCl solution is added to 10 mL of a concentrated solution of pH 5 containing acetic acid and sodium acetate. The pH of the resulting solution will be closest to:

(A) 2
(B) 3
(C) 5
(D) 7

20 What mass of sodium hydrogen carbonate is required for complete reaction with 50.0 mL of 0.100 M sulfuric acid solution?

(A) 0.210 g
(B) 0.420 g
(C) 0.840 g
(D) 4.20 g

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Masters' Initials | Candidate Number

Part B

Total marks (55)
Attempt ALL Questions
Allow about 1 hour and 45 minutes for this Part

Answer the questions in the spaces provided
Show **all** relevant working in questions involving calculations

Question 21 (3 marks) **Marks**

Polymerisation is the process of creating large molecules by reacting together many smaller molecules.

(a) Draw the molecular structure of styrene.

1

(b) Draw a segment of polystyrene that would result from the reaction of styrene monomers. Include at least three repeating units.

2

Question 22 (5 marks) **Marks**

Justify the need to monitor the conditions involved in the production of pure ethanol from glucose.

5

Question 23 (2 marks)

Ethylene, because of the instability of its double bond, is highly reactive. Write balanced chemical equations for two reactions of ethylene.

2

Question 24 (2 marks) **Marks**

Identify an instrument used to detect radiation and outline the manner in which it works.

2

Question 25 (4 marks)

Name a specific enzyme or organism used to produce a biopolymer and account for its use in the production of this polymer.

4

Question 26 (3 marks) **Marks**

The molar heat of combustion for 1-butanol is –2670 kJ mol^{-1}. Calculate the mass of 1-butanol that would be needed to raise 0.024 kg of water from 10.0 °C to 23.7 °C.

3

Masters' Initials | Candidate Number

Question 27 (3 marks) **Marks**

Draw a labelled diagram of a simple galvanic cell made from copper and zinc half-cells. Your diagram should include a label to indicate the direction of electron flow, a label to indicate the cathode and a label to indicate the site of reduction.

3

Question 28 (2 marks)

The industrial synthesis of ammonia typically takes place in the presence of a magnetite catalyst. Justify the use of a catalyst in this process.

2

Question 29 (5 marks) **Marks**

A solution is known to contain significant concentrations of chloride, phosphate and sulfate ions.

Describe a sequence of tests that could be used to confirm the presence of each of these ions. Include **one** relevant chemical equation.

5

Question 30 (5 marks) **Marks**

Sulfur dioxide is commonly used as a preservative in food and drink. The sulfur dioxide content in dried apple was determined using the following procedure:

1. 50.0 g of dried apple was blended to a fine powder.
2. The powdered dried apple was added to a conical flask containing 100 mL of water.
3. 10 mL of acidified 10%(v/v) hydrogen peroxide was added and the mixture agitated in order to extract all the sulfur dioxide from the apple and oxidise it to sulfate.
4. The resulting mixture was filtered and the residue washed with deionised water.
5. The filtrate was then treated with 5%(w/v) barium chloride solution until no further precipitation occurred.
6. The resulting mixture was filtered through a pre-weighed sintered glass crucible.
7. The residue was washed with deionised water and dried to constant mass.

The following results were recorded:

Mass of sintered glass crucible (g)	52.064 g
Mass of sintered glass crucible + precipitate (g)	52.252 g

(a) Calculate the mass of precipitate formed.

1

(b) Calculate the percentage by mass of sulfur dioxide in the dried apple.

4

Question 31 (4 marks) **Marks**

The industrial production of hydrogen by steam reforming involves the following two reactions:

1. $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ $\Delta H = +206 \text{ kJ mol}^{-1}$
2. $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$ $\Delta H = -41 \text{ kJ mol}^{-1}$

Explain the likely conditions of temperature and pressure required in each step of this process in order to maximise the yield and rate of production of hydrogen.

4

Masters' Initials | Candidate Number

Question 32 (2 marks) **Marks**

Potassium hydrogen oxalate (KHC_2O_4) is an amphiprotic compound. Construct an equation that describes its behaviour in each of the following solutions.

(a) Reaction with dilute sulfuric acid. **1**

(b) Reaction with aqueous sodium hydroxide. **1**

Question 33 (4 marks) **Marks**

Describe how you could produce a pure sample of the ester ethyl benzoate from ethanol and benzoic acid. Relevant properties of the starting materials and products are listed below; ethyl benzoate is less dense than water.

material	Melting point (°C)	Boiling point (°C)	Soluble in:
ethanol	–114	78	water, ethanol
benzoic acid	122	249	only ethanol
ethyl benzoate	–35	212	only ethanol

4

Question 34 (3 marks) **Marks**

Explain why 0.1 M solutions of acetic acid and hydrochloric acid have different concentrations of $H^+(aq)$ and yet require the same amount of NaOH(aq) to neutralise them.

3

Question 35 (4 marks)

Sulfur dioxide fumes can be removed from the exhaust gases resulting from the smelting of sulfide ores by passing the exhaust gasses through a basic solution such as calcium hydroxide.

$$2SO_2(g) + Ca(OH)_2(aq) \rightarrow Ca(HSO_3)_2(aq)$$

If 1000 L (measured at 0 °C and 100 kPa) of exhaust gases contain 5.00% sulfur dioxide by volume, calculate the mass of calcium hydroxide required to remove the SO_2 from the exhaust gases.

4

Question 36 (4 marks) **Marks**

When a drop of Universal Indicator is placed in a bottle of freshly opened carbonated water the resulting mix turns an orange colour. If this solution is then poured into a shallow petri dish, the solution turns a green colour over a period of an hour.

Explain, using Le Châtelier's Principle, the changes that are happening to the solution over the hour and explain why the colour of the Universal Indicator solution changes during this time.

4

Section II

25 marks
Attempt question 37 in this section.
Allow about 45 minutes for this section.

Answer the question in a **writing booklet**. Extra writing booklets are available.
Show **all** relevant working in questions involving calculations.

		Pages
Question 37	**Industrial Chemistry……..**	**21-25**
Question 38	**Elective 2**	
Question 39	**Elective 3**	
Question 40	**Elective 4**	
Question 41	**Elective 5**	

Question 37 (25 marks) **Marks**

(a) A chemist performed three separate experiments to analyse the following equilibrium.

$$\underset{\text{(colourless)}}{H_{2(g)}} + \underset{\text{(purple)}}{I_{2(g)}} \rightleftharpoons \underset{\text{(colourless)}}{2HI_{(g)}} \qquad \Delta H = +52 \text{ kJ mol}^{-1}$$

All three experiments were carried out at the same pressure. Two of the experiments were carried out at the same temperature, while the other was carried out at a different temperature.

The results of the experiments are shown in the table below.

Experiment	Concentration (mol^{-1})					
	Initial			At equilibrium		
	$H_{2(g)}$	$I_{2(g)}$	$HI_{(g)}$	$H_{2(g)}$	$I_{2(g)}$	$HI_{(g)}$
1	1.000	1.000	0.000	0.228	0.228	1.544
2	1.000	0.727	3.000	0.526	0.253	3.953
3	0.000	0.625	0.750	0.0175	0.637	0.715

(i) Identify which experiment was carried out at the **DIFFERENT** temperature. Explain whether this experiment was at a higher or lower temperature than that of the other two experiments. **2**

(ii) Describe how the chemist could monitor when Experiment 1 reached equilibrium. **1**

(iii) After Experiment 1 reached equilibrium, the chemist carried out a fourth experiment by doubling the concentration of H_2 while maintaining a constant temperature. Explain what would happen in the reaction vessel in response to this change **and** the effect this would have on the value of the equilibrium constant. **2**

Question 37 continued on next page.

Marks

(b) Molten sodium chloride is electrolysed in a cell using inert electrodes.

(i) Identify the product that would form at the negative electrode (cathode). **1**

(ii) State the half-equation for the reaction taking place at the positive electrode (anode). **1**

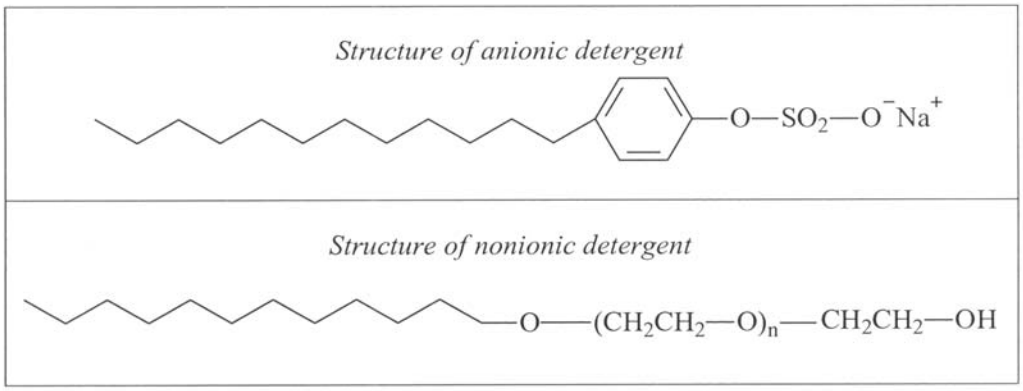
(iii) Identify a chemical test that would confirm the presence of the product produced at the positive electrode (anode). **1**

(iv) Given that molten sodium chloride has a density of 1.556 g cm^{-3}, calculate the volume of gas that would be formed when 1.00 L of molten sodium chloride is electrolysed and the gas is collected and cooled to 25 °C and 100 kPa. **3**

Question 37 continued on next page.

Marks

(c) The diagram below shows the structure of two typical synthetic detergent compounds.



(i) Define saponification. **1**

(ii) Distinguish between common soaps and these types of synthetic detergents in terms of their chemical composition, environmental impact, uses and their action as cleaning agents. **4**

Question 37 continued on next page.

Complete parts (d) and (e) in a new Answer Booklet.

(d) One step in the industrial production of sulfuric acid is the conversion of sulfur dioxide into sulfur trioxide. Describe and justify the conditions used in this process. **3**

(e) In order to find a suitable location for any industrial plant, a chemist must consider a number of fundamental criteria, including:

- Access to raw materials
- The Production process
- Environmental concerns
- Any waste product disposal
- Use and transport of the product

For each of these criteria, explain their significance in determining a suitable location for an industrial plant for the manufacture of sodium carbonate. **6**

This page is intentionally devoid of substantive content.

Data Sheet

Avogadro's constant, N_A ……		6.022×10^{23} mol^{-1}
Volume of 1 mole ideal gas:	at 100 kPa and	
	at 0 °C (273 K) ……	22.71L
	at 25 °C (298K) ……	24.79 L
Ionisation constant for water at 25°C (298.15 K), K_w …….		1.0×10^{-14}
Specific heat capacity of water ……..		4.18×10^3 Jkg^{-1}K^{-1}

Some useful formulae

$\text{pH} = -\log_{10}[H^+]$ $\qquad$ $q = mC\Delta T$

Standard Potentials

$K^+ + e^-$	$\rightleftharpoons$	$K_{(s)}$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba_{(s)}$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca_{(s)}$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na_{(s)}$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg_{(s)}$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al_{(s)}$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn_{(s)}$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2} H_{2(g)} + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn_{(s)}$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe_{(s)}$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni_{(s)}$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn_{(s)}$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb_{(s)}$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2} H_{2(g)}$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_{2(g)} + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu_{(s)}$	0.34 V
$\frac{1}{2} O_{2(g)} + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu_{(s)}$	0.52 V
$\frac{1}{2} I_{2(s)} + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2} I_{2(aq)} + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag_{(s)}$	0.80 V
$\frac{1}{2} Br_{2(l)} + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2} Br_{2(aq)} + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2} O_2 + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2} Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2} H_2O$	1.36 V
$\frac{1}{2} Cl_{2(g)} + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2} Cl_{2(aq)} + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2} F_{2(g)} + e^-$	$\rightleftharpoons$	F^-	2.89 V

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium						

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Elements with atomic numbers 112 and above have been reported but not fully authenticated.

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of data. Some data may have been modified.

1 Which of the following isotopes is radioactive?

(A) $^{13}_{5}B$

(B) $^{59}_{27}Co$

(C) $^{31}_{15}P$

(D) $^{200}_{80}Hg$

2 Which of the following statements is true about unstable isotopes?

(A) They all have an atomic number greater than 82.
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(C) They all have more neutrons than protons.
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(B) **0.81 V**
(C) 1.51 V
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(B) **There is a transfer of electrons from the metal to the hydrogen ions.**
(C) There is a transfer of electrons from the anions to the cations.
(D) There is a transfer of electrons from the cations to the anions.

5 Which of the following is true about ethanol?

(A) It has the formula CH_3COOH.
(B) **It can act as a solvent of both polar and non-polar substances.**
(C) It is the smallest possible alkanol.
(D) It is the monomer from which cellulose is produced.

6 What is the defining principle common to all condensation polymerisations?

(A) They all produce water.
(B) They are all formed by reactions across double bonds.
(C) They all involve the addition of small molecules.
(D) They all involve the ejection of small molecules.

7 What is the major industrial source of ethylene?

(A) Dehydration of ethanol.
(B) Cracking of petroleum
(C) Fermentation of sugars
(D) Lysis of polyethylene

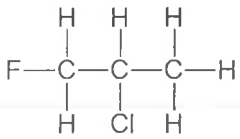
8 How many isomers are there for C_2H_3BrClF?

(A) 2
(B) 3
(C) 4
(D) 5

9 Waste water from a factory is contaminated with a significant concentration of dissolved calcium ions. Which of the following ions could also be dissolved at the highest concentration in the waste water?

(A) chloride
(B) carbonate
(C) phosphate
(D) sulfate

10 What is the correct IUPAC name for the following compound?

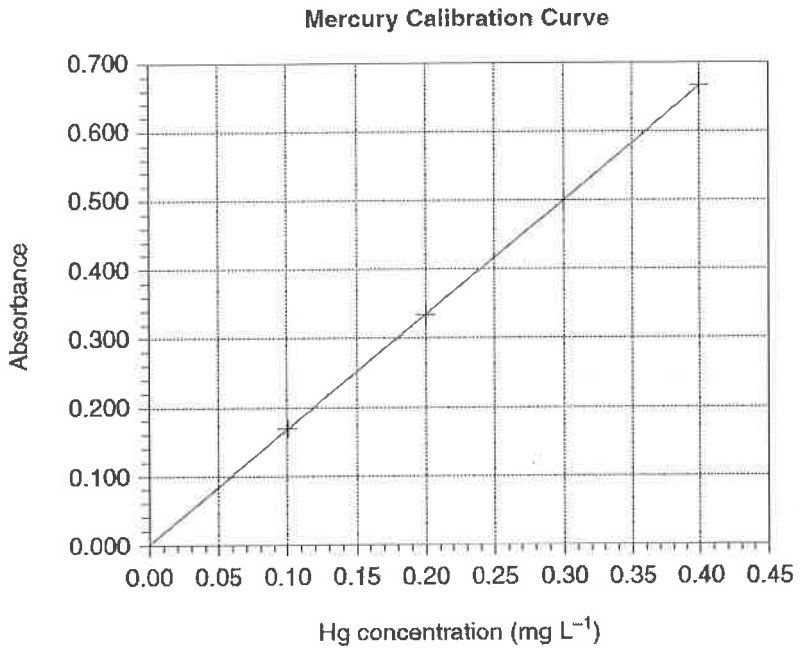


(A) 2-chloro-1-fluoropropane
(B) 1-fluoro-2-chloropropane
(C) 2-chloro-3-fluoropropane
(D) 3-fluoro-2-chloropropane

11 Which of the following is a balanced chemical equation representing the incomplete combustion of an alkane?

(A) $C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(l)}$
(B) $C_2H_5OH_{(l)} + 2O_{2(g)} \rightarrow CO_{(g)} + C_{(s)} + 3H_2O_{(l)}$
(C) $C_2H_{4(g)} + 2O_{2(g)} \rightarrow 2CO_{(g)} + 2H_2O_{(l)}$
(D) $C_4H_{10(g)} + 5O_{2(g)} \rightarrow CO_{2(g)} + 3CO_{(g)} + 5H_2O_{(l)}$

12 Below is a calibration curve generated when using an atomic absorption spectrometer (AAS) to detect mercury.



A 500 mL sample of unknown mercury concentration gives an absorbance of 0.500 on the same instrument.

What is the concentration of mercury in the unknown sample?

(A) 3.00×10^{-1} M
(B) 1.50×10^{-2} M
(C) 1.50×10^{-3} M
(D) 1.50×10^{-6} M

13 All the strontium ions present in a 250 mL solution were precipitated by reaction with excess sulfate ions. The mass of the dried strontium sulfate obtained after filtration, washing and drying was 0.353 g.

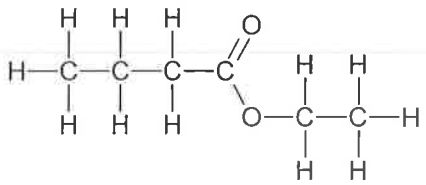
What was the concentration of strontium ions in the original solution?

(A) 168 mg L^{-1}
(B) 477 mg L^{-1}
(C) 673 mg L^{-1}
(D) 1412 mg L^{-1}

14 Which of the following indicators would best identify the equivalence point of the titration of 0.1 M ammonia with 0.1 M hydrochloric acid?

(A) methyl orange
(B) phenolphthalein
(C) bromothymol blue
(D) litmus

15 The structural formula of an ester with a strawberry fragrance is shown below:



Which alkanoic acid and alkanol could be used to synthesise this ester?

	alkanol	alkanoic acid
(A)	ethanol	propanoic acid
(B)	**ethanol**	**butanoic acid**
(C)	1-butanol	ethanoic acid
(D)	1-propanol	ethanoic acid

16 Which equation below best represents hydrogen chloride gas acting as a Brønsted-Lowry acid?

(A) $HCl(g) \xrightarrow{H_2O} HCl(aq)$
(B) $HCl(g) \xrightarrow{H_2O} H^+(aq) + Cl^-(aq)$
(C) $HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$
(D) $2HCl(g) + Sn(s) \rightarrow H_2(g) + SnCl_2(s)$

17 Which of the following solutions contains the highest molar concentration of acid?

(A) **An acetic acid solution with a pH of 3.**
(B) A hydrochloric acid solution with a pH of 3.
(C) A sulfuric acid solution with a pH of 3.
(D) A citric acid solution with a pH of 3.

18 Two drops (0.1 mL) of 0.01 M HCl solution is added to 10 mL of a HCl solution with a pH of 5. The pH of the resulting solution will be closest to:

(A) 3
(B) **4**
(C) 5
(D) 6

19 Two drops (0.1 mL) of 0.01 M HCl solution is added to 10 mL of a concentrated solution of pH 5 containing acetic acid and sodium acetate. The pH of the resulting solution will be closest to:

(A) 2
(B) 3
(C) **5**
(D) 7

20 What mass of sodium hydrogen carbonate is required for complete reaction with 50.0 mL of 0.100 M sulfuric acid solution?

(A) 0.210 g
(B) 0.420 g
(C) **0.840 g**
(D) 4.20 g

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Part B

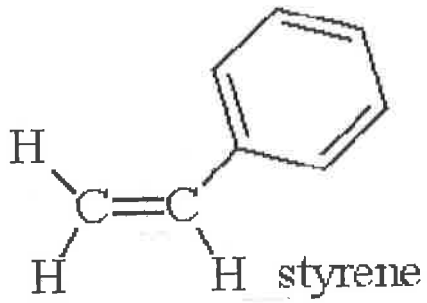
Total marks (55)
Attempt ALL Questions
Allow about 1 hour and 45 minutes for this Part

Answer the questions in the spaces provided
Show **all** relevant working in questions involving calculations

Question 21 (3 marks) **Marks**

Polymerisation is the process of creating large molecules by reacting together many smaller molecules.

(a) Draw the molecular structure of styrene. **1**



(b) Draw a segment of polystyrene that would result from the reaction of styrene monomers. Include at least three repeating units. **2**

Must include

- Minimum of 3 units
- No double bonds
- Benzene ring every second carbon
- No hydrogens at the end

Question 22 (5 marks) **Marks**

Justify the need to monitor the conditions involved in the production of pure ethanol from glucose.

5 Marks	*Justifies need to monitor* 4 of the following parameters PLUS fermentation equation. **(Temp, anaerobic, yeast/zymase) of fermentation.** **Temperature of distillation.**
4 Marks	*Justifies need to monitor* 3 of the parameters PLUS *identifies* 1parameter OR fermentation equation *Justifies need to monitor* 2 of the following parameters PLUS *identifies* 2 parameter PLUS fermentation equation
3 Marks	*Justifies need to monitor* 2 of the parameters PLUS *identifies* 1parameter OR fermentation equation OR *Justifies need to monitor* 1 of the following parameters PLUS *identifies* 2 parameters PLUS fermentation equation OR *Justifies need to monitor* 1 of the following parameters PLUS *identifies* 3 parameters *Identifies* 4 parameters PLUS fermentation equation *Identifies* 5 parameters
2 Marks	*Justifies need to monitor* 1 of the parameters PLUS *identifies* 1 parameter OR fermentation equation *Identifies* 2 parameters PLUS fermentation equation *Identifies* 3 parameters
1 Mark	*Identifies* 2 parameters OR *identifies* 1 parameter plus equation

5

Question 22 (5 marks) 5 **Marks**

Justify the need to monitor the conditions involved in the production of pure ethanol from glucose.

Fermentation of glucose: $C_6H_{12}O_6 \xrightarrow{\text{yeast enzyme}} 2C_2H_6O + 2CO_2$

Reaction requires specific conditions which must be monitored including:

- ~35°C (higher denatures enzymes so temperature must be carefully monitored).
- Anaerobic – O_2 levels must be monitored & kept to minimum otherwise yeast enzyme will metabolise glucose with oxygen in more favourable metabolic pathway
- Ethanol concentration <15% – higher than this & the ethanol will kill the yeast enzyme so must be monitored (reaction progress must be monitored by measuring mass loss due to CO_2)
- Bacteriacidal pH achieved to prevent bacterial growth (pH must be monitored)
- Further to produce pure ethanol, distillation must occur to increase 15% ethanol → 98+% → During distillation, temperature must be carefully monitored so 87°C ≤ T < 100°C, to exploit the difference in boiling point between water & ethanol

Question 23 (2 marks) 2

Ethylene, because of the instability of its double bond, is highly reactive. Write balanced chemical equations for two reactions of ethylene.

Ethylene and Bromine: (organic solvent)

$$C_2H_{4(g)} + Br_{2(aq)} \xrightarrow{CCl_4} C_2Br_2H_{4(aq)}$$

Ethylene hydrated to ethanol:

$$H_2O_{(l)} + C_2H_{4(g)} \xrightarrow{H_2SO_{4(aq)}} C_2H_6O_{(l)}$$

Question 23 (2 marks)

Ethylene, because of the instability of its double bond, is highly reactive. Write balanced chemical equations for two reactions of ethylene.

Any 2 equations, correctly written and balanced, for reactions of ethylene.

2

Question 24 (2 marks)

Identify an instrument used to detect radiation and outline the manner in which it works.

- Name -1
- Brief description – 1

eg

*Geiger Counter – (Argon) gas in chamber is ionised ....

*Cloud chamber –radiation ionises (ethanol which causes) air (to/which) condense(s), forming cloud/vapour trails....

*Film Badges – radiation blackens silver halide emulsion ....

*Scintillation counter – radiation makes material fluoresce..... (photons converted to electric impulse by photo electric effect).

2

Question 25 (4 marks)

Name a specific enzyme or organism used to produce a biopolymer and account for its use in the production of this polymer.

4 Marks	*Identifies* biopolymer AND name of organism/enzyme, AND provides some explanation of the production process AND includes some chemistry (eg equation or chemical structure)
3 Marks	*Identifies* biopolymer AND name of organism/enzyme, AND provides some explanation of the production process
2 Marks	*Identifies* biopolymer AND name of organism/enzyme OR provides some explanation of the production process
1 Mark	*Identifies* biopolymer

4

Question 26 (3 marks) **Marks**

The molar heat of combustion for 1-butanol is –2670 kJ mol^{-1}. Calculate the mass of 1-butanol that would be needed to raise 0.024 kg of water from 10.0 °C to 23.7 °C.

$2670 \times 10^3 = (24 \times 4.18 \times 13.7) / n$ - 1 Mark

$n = 5.1475 \times 10^{-4}$ - 1 Mark

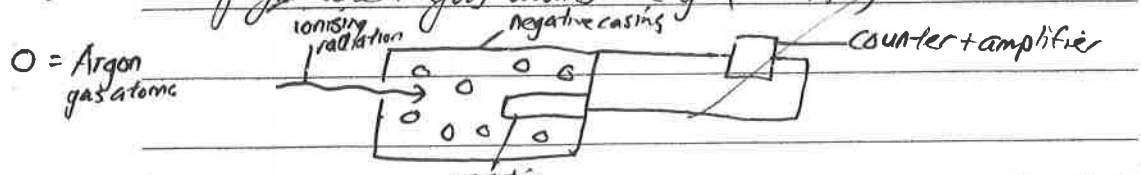
mass = $5.1475 \times 10^{-4} \times (16 + 4 \times 12.01 + 10.08)$
= 0.038(15)g - 1 Mark

3

Question 24 (2 marks) **Marks**

Identify an instrument used to detect radiation and outline the manner in which it works.

- The Geiger Counter is used to detect ionising radiation & it works via the ionisation of gas inert gas atoms e.g. (of Ar) 2



- As the ionising radiation enters the counter, it ionises the Ar atoms causing the removed electrons (from Ar) are attracted to the positive electron and flow through the entered current causing a current. This is detected by the counter + amplifier which produces a clicking sound. The more intense the clicking sound, the more ionising radiation there is.

Question 25 (4 marks)

Name a specific enzyme or organism used to produce a biopolymer and account for its use in the production of this polymer.

- Biopolymers are polymers produced from organisms. 4
- Alcaligenes Eutrophus produces biopol (or co-hydroxybutyrate-hydroxyvalerate)
- Alcaligenes Eutrophus is essential to the production of Biopol as it produces Biopol as a by-product of breaking down glucose (cellular respiration)
- To induce the ~~creation~~ production of Biopol in Alcaligenes Eutrophus, a high valeric acid, high glucose environment is provided and then a nitrogen deficiency is created
- The produced biopol can then be removed via hot trichloromethane.
- Whilst it is essential to the production of Biopol, through genetic engineering, scientists have been able to isolate the gene responsible for Biopol production and transfer it to E.Coli thus reducing the use of Alcaligenes Eutrophus in Biopol production as scientists are more familiar with working with E.Coli and are ∴ more efficient
- Thus Alcaligenes Eutrophus is used to produce Biopol, but more efficient alternatives are being developed. 4

Very good!

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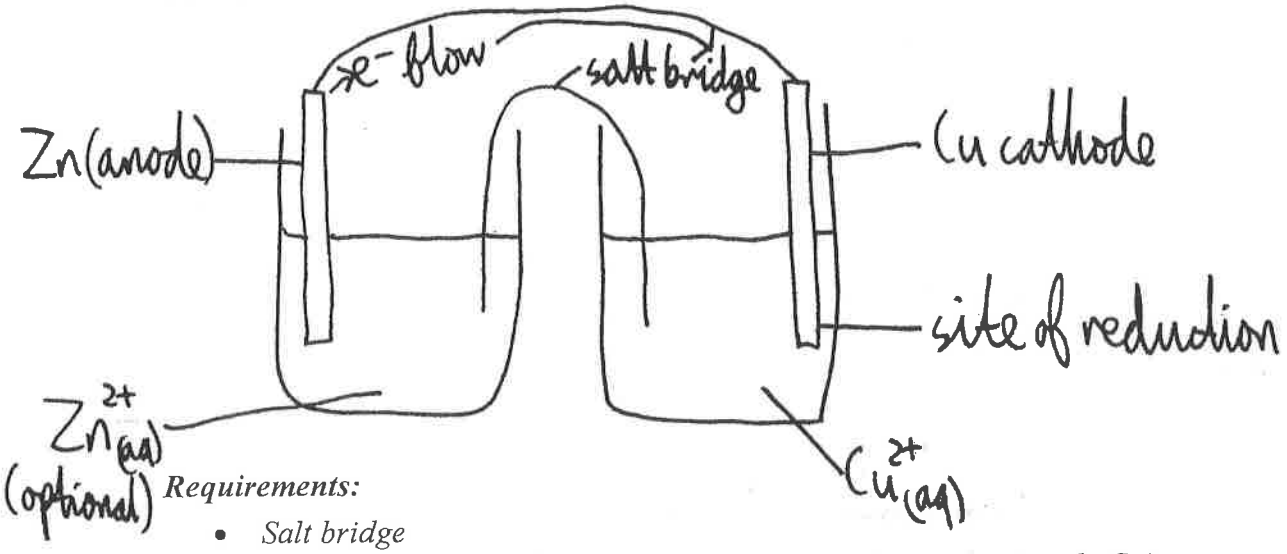
Question 27 (3 marks) **Marks**

Draw a labelled diagram of a simple galvanic cell made from copper and zinc half-cells. Your diagram should include a label to indicate the direction of electron flow, a label to indicate the cathode and a label to indicate the site of reduction.

3



Requirements:

- *Salt bridge*
- *Cathode indicated (electrode submerged in catholyte, commonly Cu)*
- *Site of reduction indicated (interface between the cathode and the catholyte). The label needs to point at this, not just vaguely into the solution or at the beaker.*
- *$Cu^{2+}_{(aq)}$ in catholyte*
- *e^- flow from anode to cathode*

(−1) per error

Question 28 (2 marks)

The industrial synthesis of ammonia typically takes place in the presence of a magnetite catalyst. Justify the use of a catalyst in this process.

2

*2 marks: catalyst increases rate of reaction without increasing temperature; enables a **lower temperature** to be used for a given reaction rate, which increases **yield**.*

1 mark for general statement about increasing rate of reaction due to decreased activation energy.

Question 29 (5 marks) **Marks**

A solution is known to contain significant concentrations of chloride, phosphate and sulfate ions.

Describe a sequence of tests that could be used to confirm the presence of each of these ions. Include **one** relevant chemical equation.

5

5 marks:

- *3 tests in correct sequence + equation + excess/filtration details*

4 marks: either

- *3 tests in correct sequence + equation*
- *2 tests in correct sequence + equation + excess/filtration details*

3 marks:

- *2 tests in correct sequence + equation*

2 marks: either

- *2 tests (if no differentiation*
- *1 test + equation*

1 mark: either

- *1 test*
- *equation*

e.g.

1. *Add excess zinc nitrate[1] solution, forming a white precipitate of zinc phosphate.*
2. *Filter out the zinc phosphate.*
3. *To the filtrate add excess barium nitrate solution, forming a white precipitate of barium sulfate.*
4. *Filter out the barium sulfate.*
5. *To the filtrate, add silver nitrate, forming a white precipitate of silver chloride.*

Alternatively:

1. *Acidify the mixture with dilute nitric acid (to prevent formation of insoluble phosphates).*
2. *Add excess barium nitrate solution, forming a white precipitate of barium sulfate.*
3. *Filter out the barium sulfate.*
4. *To the filtrate add ammonia until the solution is slightly alkaline. A white precipitate of barium phosphate will form.*
5. *Add more barium nitrate solution to ensure complete precipitation of phosphate.*
6. *Filter out the barium phosphate.*
7. *To the filtrate, add silver nitrate, forming a white precipitate of silver chloride.*

Notes:

1. Must not add a counterion that would interfere with the subsequent tests (e.g. chloride or sulfate). Nitrate is always safe!

Question 30 (5 marks) **Marks**

Sulfur dioxide is commonly used as a preservative in food and drink. The sulfur dioxide content in dried apple was determined using the following procedure:

1. 50.0 g of dried apple was blended to a fine powder.
2. The powdered dried apple was added to a conical flask containing 100 mL of water.
3. 10 mL of acidified 10%(v/v) hydrogen peroxide was added and the mixture agitated in order to extract all the sulfur dioxide from the apple and oxidise it to sulfate.
4. The resulting mixture was filtered and the residue washed with deionised water.
5. The filtrate was then treated with 5%(w/v) barium chloride solution until no further precipitation occurred.
6. The resulting mixture was filtered through a pre-weighed sintered glass crucible.
7. The residue was washed with deionised water and dried to constant mass.

The following results were recorded:

Mass of sintered glass crucible (g)	52.064 g
Mass of sintered glass crucible + precipitate (g)	52.252 g

(a) Calculate the mass of precipitate formed.

0.188 g **1**

(b) Calculate the percentage by mass of sulfur dioxide in the dried apple.

4

$m(BaSO_4) = 0.188\ g$

$m(SO_2) = 0.188\ g \times \frac{64.07}{233.37} = 0.0516\ g$

$\%(SO_2) = \frac{0.0516\ g}{50.0\ g} \times \frac{100}{1} = 0.103\%\ (to\ 3\ significant\ figures)$

1 mark for each step, 1 mark for answer to 3 significant figures.

Some boys gave their answer to 1 or 2 significant figures due to the hydrogen peroxide or barium chloride data, but these are present in excess and are not used in the calculations!

Question 31 (4 marks) **Marks**

The industrial production of hydrogen by steam reforming involves the following two reactions:

1. $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ $\Delta H = +206 \text{ kJ mol}^{-1}$
2. $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$ $\Delta H = -41 \text{ kJ mol}^{-1}$

Explain the likely conditions of temperature and pressure required in each step of this process in order to maximise the yield and rate of production of hydrogen.

4

4 marks:

- *Explains likely conditions of temperature on yield and reaction rate for both reactions*
  AND
- *Explains likely conditions of pressure on yield and reaction rate for both reactions*

3 marks:

- *As for 4 marks, but missing one point (most commonly the relationship between pressure and reaction rate).*

2 marks: either

- *Identifies likely conditions of temperature and pressure*
  AND
- *Explains effect of temperature **or** pressure on yield or reaction rate for **both** reactions*
  OR
- *Explains effect of temperature **and** pressure on yield or reaction rate for **one** reaction*

1 mark:

- *Identifies likely conditions of temperature and pressure.*
- *Explains effect of temperature **or** pressure on yield **or** reaction rate.*

e.g.

Reaction rate: both high pressure and high temperature favour high reaction rate.

Yield: High yields of hydrogen are favoured by high temperature and low pressure in reaction 1 and only by low temperature in reaction 2 (pressure has no effect on yield).

Reaction 1: High temperature favours high yield and reaction rate; pressure is a compromise and should be kept as low as practical (for high yield) without sacrificing reaction rate.

Reaction 2: Compromise temperature (low temperature favours high yield but low reaction rate); pressure should be increased in order to increase reaction rate.

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Question 32 (2 marks) **Marks**

Potassium hydrogen oxalate (KHC_2O_4) is an amphiprotic compound. Construct an equation that describes its behaviour in each of the following solutions.

(a) Reaction with dilute sulfuric acid.

$KHC_2O_{4(aq)} + H_2SO_{4(aq)} \rightarrow H_2C_2O_{4(aq)} + KHSO_{4(aq)}$

or $2\,KHC_2O_{4(aq)} + H_2SO_{4(aq)} \rightarrow 2\,H_2C_2O_{4(aq)} + K_2SO_{4(aq)}$

(b) Reaction with aqueous sodium hydroxide.

$KHC_2O_{4(aq)} + NaOH_{(aq)} \rightarrow KNaC_2O_{4(aq)} + 1\,H_2O_{(l)}$

or $HC_2O_4^-{}_{(aq)} + OH^-{}_{(aq)} \rightarrow C_2O_4^{2-}{}_{(aq)} + H_2O$

Question 33 (4 marks) **Marks**

Describe how you could produce a pure sample of the ester ethyl benzoate from ethanol and benzoic acid. Relevant properties of the starting materials and products are listed below; ethyl benzoate is less dense than water.

material	Melting point (°C)	Boiling point (°C)	Soluble in:
ethanol	–114	78	water, ethanol
benzoic acid	122	249	only ethanol
ethyl benzoate	–35	212	only ethanol

1. Dissolve benzoic acid in ethanol - add concentrated H_2SO_4 catalyst. 4
2. Mention reasonable quantities eg 5g benzoic acid, excess ethanol
3. Reflux
4. Work up with water to remove sulfuric acid. Neutralise unreacted benzoic acid with base. Seperating funnel to separate ethyl benzoate.

- Somewhat holistically marked as there are many ways to answer question

Question 34 (3 marks) **Marks**

Explain why 0.1 M solutions of acetic acid and hydrochloric acid have different concentrations of $H^+(aq)$ and yet require the same amount of NaOH(aq) to neutralise them.

2 marks - Explain that Hydrochloric 3
And is a strong acid and 100% ionised
whilst acetic acid is weak and much less ionised
3rd mark
- discuss (a) equilibrium dissociation of weak and
~~or~~ when ^-OH reacts with H^+
or (b) ^-OH is strong base and will
react with acidic hydrogen on
acetic acid.

Question 35 (4 marks)

Sulfur dioxide fumes can be removed from the exhaust gases resulting from the smelting of sulfide ores by passing the exhaust gasses through a basic solution such as calcium hydroxide.

$$2SO_2(g) + Ca(OH)_2(aq) \rightarrow Ca(HSO_3)_2(aq)$$

- 3. s.f.

If 1000 L (measured at 0 °C and 100 kPa) of exhaust gases contain 5.00% sulfur dioxide by volume, calculate the mass of calcium hydroxide required to remove the SO_2 from the exhaust gases.

1 mark calculation of 50 L SO_2 4

1 mark calculation moles $SO_2 = \frac{50}{22.71} = 2.203$ m

1 mark calculation moles $Ca(OH)_2 = \frac{2.203}{2} = 1.1015$

1 mark - mass $Ca(OH)_2 = 81.6$ g to 3 s.f.

Question 36 (4 marks) **Marks**

When a drop of Universal Indicator is placed in a bottle of freshly opened carbonated water the resulting mix turns an orange colour. If this solution is then poured into a shallow petri dish, the solution turns a green colour over a period of an hour.

Explain, using Le Châtelier's Principle, the changes that are happening to the solution over the hour and explain why the colour of the Universal Indicator solution changes during this time.

4

~~Equation~~ Equation - Equilibrium
Le Chateliers Principle,
Acidity caused by carbonic acid
Indicator change caused by decreasing acidity of solution as time proceeds

Question 37 (25 marks) **Marks**

(a) A chemist performed three separate experiments to analyse the following equilibrium.

$$\underset{\text{(colourless)}}{H_{2(g)}} + \underset{\text{(purple)}}{I_{2(g)}} \rightleftharpoons \underset{\text{(colourless)}}{2HI_{(g)}} \qquad \Delta H = +52 \text{ kJ mol}^{-1}$$

All three experiments were carried out at the same pressure. Two of the experiments were carried out at the same temperature, while the other was carried out at a different temperature.

The results of the experiments are shown in the table below.

Experiment	Concentration (mol^{-1})					
	Initial			At equilibrium		
	$H_{2(g)}$	$I_{2(g)}$	$HI_{(g)}$	$H_{2(g)}$	$I_{2(g)}$	$HI_{(g)}$
1	1.000	1.000	0.000	0.228	0.228	1.544
2	1.000	0.727	3.000	0.526	0.253	3.953
3	0.000	0.625	0.750	0.0175	0.637	0.715

(i) Identify which experiment was carried out at the **DIFFERENT** temperature. Explain whether this experiment was at a higher or lower temperature than that of the other two experiments. **2**

1 mark – identifies Experiment 2AND that it was done at a higher temperature OR calculates correct K values (45.8 and 117)

1 mark – explanation that K2 > K1 and K3, therefore more product formed, and as forward reaction is endothermic, this means higher temperature.

Too many boys picked Expt 3 since HI went down??
Some boys were lucky to get 1st mark as identified Expt 2 at higher temp for completely wrong reason.

(ii) Describe how the chemist could monitor when Experiment 1 reached equilibrium.

1 mark - When the colour stops changing.

Did not pay when temperature stops changing as question says temperature was controlled and constant. Did not pay any sampling mechanisms that involved opening the system.

1

(iii) After Experiment 1 reached equilibrium, the chemist carried out a fourth experiment by doubling the concentration of H_2 while maintaining a constant temperature. Explain what would happen in the reaction vessel in response to this change **and** the effect this would have on the value of the equilibrium constant. **2**

1 mark – uses LCP to explain the system shifts to RHS to counteract change, hence more HI formed.

1 mark – explains that since temperature is held constant, K will stay the same.

Too many boys said K would increase and mixed up Q/K.

(b) Molten sodium chloride is electrolysed in a cell using inert electrodes.

(i) Identify the product that would form at the negative electrode (cathode). **1**

Sodium metal

(ii) State the half-equation for the reaction taking place at the positive electrode (anode).

$2Cl^- \rightleftharpoons Cl_{2(g)} + 2e^-$

1mark CE given if (i) and (ii) reversed

Too many boys gave equations for aqueous sodium chloride. **1**

(iii) Identify a chemical test that would confirm the presence of the product produced at the positive electrode (anode).

Bleaching of moist litmus paper, starch/Iodide test.

Did not pay chloride test e.g. ppt of AgCl as chloride is not the product.
1mark CE given if answer is correct for product given in (ii)

1

(iv) Given that molten sodium chloride has a density of 1.556 g cm^{-3}, calculate the volume of gas that would be formed when 1.00 L of molten sodium chloride is electrolysed and the gas is collected and cooled to 25 °C and 100 kPa. **3**

Sample answer

$2NaCl_{(l)} \rightarrow 2Na_{(s)} + Cl_{2(g)}$

Density = m/ V
m(NaCl) = density x V = 1.556 * 1000 = 1556g

n(NaCl) = m / FW = 1556 / 58.44 = 26.625 moles

$n(Cl_2) = ½ n (NaCl)$

$V(Cl_2) = ½ * 26.625 * 24.79 = 330 L$

Marks	Marking guidelines
3	• Calculates volume of Cl_2 gas to be 330 L.
2	• Makes one error in calculation
1	• With working shown, either calculates volume of gas, mass of NaCl OR moles of chlorine or sodium chloride.

Many boys calculated volume to be 660L as they did not write equation.
Many boys converted cm^{-3} to L incorrectly.
Marks given when wrong equation used if working could be followed.

(c) The diagram below shows the structure of two typical synthetic detergent compounds.

(i) Define saponification. **1**

1 mark - Any 3 underlined points required: Alkaline hydrolysis of fats/oils to make soap and glycerol.

(ii) Distinguish between common soaps and these types of synthetic detergents in terms of their chemical composition, environmental impact, uses and their action as cleaning agents. 4

Sample answer

	Soap	Anionic	Non-ionic
Chemical composition	Similar to anionic shown except the head is carboxylate ion.	Different head (benzene sulfonate shown) to soap. Petroleum product.	Has hydrophilic linkages mid chain and no charged heads.
Environmental impact	Little impact as biodegradable.	Initial branched chain detergents caused 'rivers of foam' but now non-branched used.	Detergents tend to use builders and phosphates leading to eutrophication issues.
Uses	Personal hygiene	Dishwashing liquids; laundry detergents; toothpaste; used in hard water (ppts as scum) or low pH as soap will not lather.	Applications that require little to no foaming e.g. dishwashers; front loading washing machines
Cleaning action	Cleans by forming micelles which stabilise grease/fats as emulsion in water, which are then rinsed away.	Identical to soap	*Do not form micelles – mostly work by enhancing other cleaning detergents – this info was not required in answer.*

Marks	Marking guidelines
4	• Provides a thorough **comparison** of soap and two types detergents in terms of: o Chemical composition o Environmental impact o Uses o Cleaning action • Refers to diagrams given.
3	• Missing one point from 4 mark list – see codes below
2	• Provides two relevant explicit comparisons.
1	• Provides any relevant comparison.

Missing or insufficient detail
CC – chemical composition (mostly missing structure of soap)
E – Environmental impact
U – Uses
CA – cleaning action
D – did not distinguish between them (usually just brain-dumped info)

(d) One step in the industrial production of sulfuric acid is the conversion of sulfur dioxide into sulfur trioxide. Describe and justify the conditions used in this process. **3**

3 marks

- *Needs to include full equation,*
- *Discuss the compromise for temperature: reaction rate vs yield regarding the forward reaction being exothermic/LCP, with detail of how temperature affects reaction rate*
- *Discuss catalyst and HOW it effects the reaction rate by lowering activation energy required*
- *Pressure not as important as an increase favours SO_3 production but not too much required as expensive so only 1-2 atm*
- *Full marks also given if catalyst not discussed but excess oxygen and removal of SO_3*

2 marks

- *Equation*
- *Only temperature and pressure discussed*

1 mark

- *General statements and an equation*

(e) In order to find a suitable location for any industrial plant, a chemist must consider a number of fundamental criteria, including:

- Access to raw materials
- The Production process
- Environmental concerns
- Any waste product disposal
- Use and transport of the product

For each of these criteria, explain their significance in determining a suitable location for an industrial plant for the manufacture of sodium carbonate. **6**

Note: Holistically marked

6 marks

- *Needs an equation*
- *Clearly laid out with each criteria individually discussed or statement as to why some where combined*
- *Complete discussion of each criterion rather than statements and a clear decision as to which is more important particularly with reference to access to raw materials.*

5 marks

- *Either a good discussion on all topics but missing the equation, or*
- *Includes equation but missing some important detail in discussion like $CaCO_3$ in raw materials or power source in production process*
- *Generally well laid out*

4 marks

- *Generally a good discussion but missing a few bits and pieces throughout or has some general statements*
- *Or 5 marks but no equation*
- *Messy layout*

3 Marks

- *Statements rather than discussion or,*
- *Not well laid out, or*
- *Missing multiple important points through out*
- *Or a 4 mark discussion but no equation*

2 Marks

- *Equation*
- *Statements*
- *Messy*

1 Mark

- *Equation and some attempt*

Generally boys covered most ideas but made statements rather than pinpointing some key areas in the environmental, raw materials and production process criteria, so full marks could not be given.

Many forgot the overall equation which would have gained them 1 mark.

Using clear titles for each criterion would have helped many boys, and their hand writing at times was illegible making it hard to follow any of their discussion.