**Insert School Logo**

**Semester Two**

**Examination 2023**

**Question/Answer booklet**

**CHEMISTRY**

**UNIT 1+2**

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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***TIME ALLOWED FOR THIS PAPER***

Reading time before commencing work: Ten minutes

Working time for the paper: Three hours

***MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER***

**To be provided by the supervisor:**

This Question/Answer Booklet

Multiple-choice Answer Sheet

Chemistry Data Book

**To be provided by the candidate:**

Standard items: pens, pencils, eraser or correction fluid, ruler, highlighter.

Special items: calculators satisfying the conditions set by the SCSA for this subject.

***IMPORTANT NOTE TO CANDIDATES***

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

**Structure of this paper**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Section | Number of questions available | Number of questions to be answered | Suggested working time  (minutes) | Marks available | Percentage of exam |
| Section One:  Multiple-choice | 25 | 25 | 50 | 25 | 25 |
| Section Two:  Short answer | 9 | 9 | 60 | 77 | 35 |
| Section Three:  Extended answer | 5 | 5 | 70 | 88 | 40 |
|  |  |  |  | **Total** | 100 |
| Final percentage | | x 25 + x 35 + x 40 = | | | % |

**Instructions to candidates**

1. Answer the questions according to the following instructions.

Section One: Answer all questions on the separate Multiple-choice Answer Sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Sections Two and Three: Write your answers in this Question/Answer Booklet.

2. When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

3. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

4. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

* + Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
  + Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

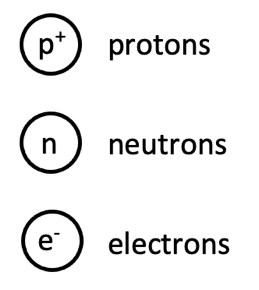
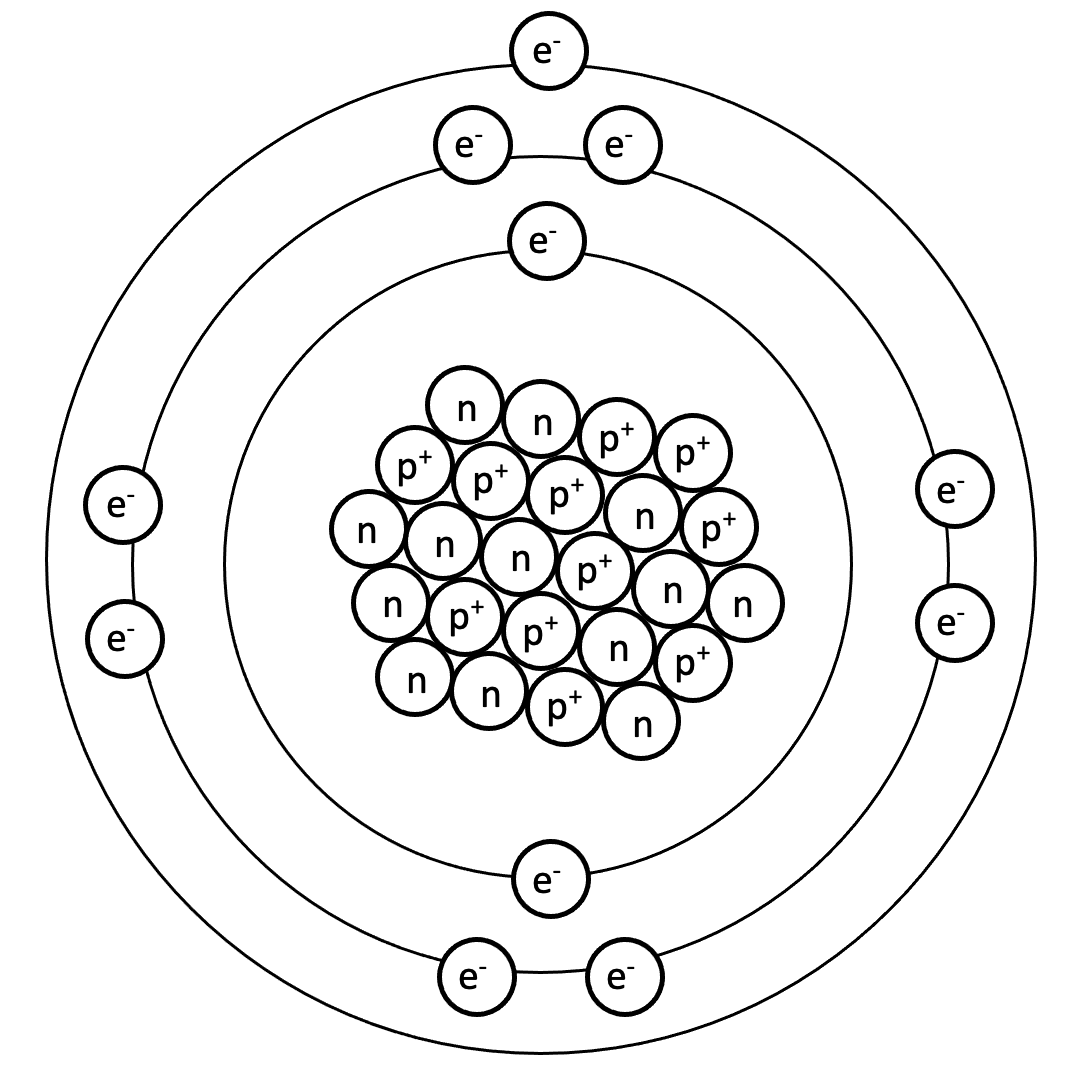
5. The Chemistry Data Book is **not** handed in with your Question/Answer Booklet.

**Section One: Multiple-choice 25% (25 marks)**

This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 50 minutes.

**Questions 1 and 2 refer to the species represented in the following diagram.**



1. Which of the following statements regarding this species is **not** correct?

1. The atomic number is 13.
2. The mass number is 24.
3. The electrons are in a ground state arrangement.
4. This species is neutral.

2. In a chemical reaction, this species would most likely

1. gain electrons.
2. share electrons.
3. form covalent bonds.
4. form ionic bonds.

3. Consider the partially completed table below, showing the name and formula of several different compounds.

|  |  |
| --- | --- |
| **Name** | **Formula** |
| zinc sulfite | **X** |
| phosphoric acid | **Y** |
| **Z** | Sn(NO3)2 |

Which of the following correctly completes this table?

**X Y Z**

1. ZnSO3 H2PO3 tin(II) nitride
2. ZnSO4 H3PO4 tin(II) nitride
3. ZnSO3 H3PO4 tin(II) nitrate
4. ZnSO4 H2PO3 tin(II) nitrate

4. Which of the following processes is exothermic?

(a) Glaciers melting.

(b) Steam condensing on a bathroom mirror.

(c) A puddle evaporating in the sunshine.

(d) Water boiling in a kettle.

5. Water exhibits many unique properties, such as an uncharacteristically low

(a) melting point.

(b) boiling point.

(c) density in solid compared to liquid state.

(d) surface tension.

6. Hydrochloric acid was poured over a sample of manganese hydroxide pellets. Which of the following correctly shows the balanced ionic equation for the chemical reaction that would occur?

1. OH-(aq) + H+(aq) → H­2O(l)
2. MnOH(s) + H+(aq) → Mn2+(aq) + H2O(l)
3. Mn(OH)2(s) + 2 H+(aq) → Mn2+(aq) + 2 H2O(l)
4. Mn(OH)2(s) + 2 HCl(aq) → MnCl2(aq) + 2 H2O(l)

7. Which of the following correctly shows a conversion typically occurring in the catalytic converter of a motor vehicle?

1. N2(g) → NO2(g)
2. CO(g) → CO2(g)
3. NO(g) → NO2(g)
4. CO2(g) → CH4(g)

8. Metallic bonding can be described as the strong electrostatic attraction between

1. protons and electrons.
2. cations and anions.
3. cations and delocalised electrons.
4. nuclei and shared electrons.

9. Element X can form chemical bonds with nitrogen to produce the compound NX3. The electron configuration of element X is most likely

1. 2, 6.
2. 2, 8.
3. 2, 8, 3.
4. 2, 8, 7.

10. Which of the following water purification processes is not always common to both groundwater and seawater treatment?

1. Filtration
2. Desalination
3. Chlorination
4. Fluoridation

11. The diagram below provides information about selected acid-base indicators, and their associated colours at various pH levels.

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

pH

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| methyl orange | red | yellow | | |
| phenolphthalein | colourless | | | pink |
| litmus | red | | blue | |

Samples of three (3) unknown solutions, A, B and C, were tested with each of these indicators. The results collected are displayed in the table below.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **A** | **B** | **C** |
| methyl orange | yellow | yellow | yellow |
| phenolphthalein | colourless | colourless | pink |
| litmus | blue | red | blue |

Rank the 3 unknown solutions in order of decreasing (i.e. highest to lowest) hydrogen ion concentration.

1. B > A > C
2. C > A > B
3. B > C > A
4. A > B > C

**Questions 12, 13 and 14 refer to the following chromatographic analysis.**

Elevated levels of the hormone cortisol can be associated with depression. The drug dexamethasone has been shown to lower cortisol levels, and thus has potential applications in treating depression.

High pressure liquid chromatography (HPLC) can be used to determine the level of cortisol in a person’s blood plasma. The chromatograms below, show the results of HPLC analysis performed on a sample of blood plasma taken from a patient;

**A:** before taking dexamethasone.

**B:** 12 hours after taking dexamethasone.

**Chromatogram A Chromatogram B**

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1.0 –

0.9 –

0.8 –

0.7 –

0.6 –

0.5 –

0.4 –

0.3 –

0.2 –

0.1 –

Absorbance

Retention time

1. prednisone

2. cortisol

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1.0 –

0.9 –

0.8 –

0.7 –

0.6 –

0.5 –

0.4 –

0.3 –

0.2 –

0.1 –

Absorbance

Retention time

1. prednisone

2. cortisol

Both samples were spiked with the steroid prednisone which acted as in internal standard.

This analysis was performed using reverse-phased HPLC, which utilises a non-polar stationary phase with a polar mobile phase.

12. Which of the following inferences is supported by the data above?

1. Prednisone is a more polar compound than cortisol.
2. Prednisone exhibits stronger interactions with the stationary phase than cortisol.
3. Cortisol has a lower molecular mass than prednisone.
4. Cortisol moves through the chromatography column more quickly than prednisone.

13. The data suggests that dexamethasone causes an approximately

1. 20% reduction in cortisol.
2. 30% reduction in cortisol.
3. 40% reduction in cortisol.
4. 50% reduction in cortisol.

14. Calibration curves are often used in HPLC analysis, for the purpose of

1. confirming the identity of a substance.
2. determining the concentration of a substance.
3. minimising systematic error in the procedure.
4. minimising random error in the procedure.

15. Which of the following could be described as an element containing chemical bonds which are formed by the sharing of electrons?

(a) N2(g)

(b) Zn(s)

(c) CO2(g)

(d) Ar(g)

16. One mole of ethanoic acid would contain

1. 6.022 x 1023 atoms of carbon.
2. 6.022 x 1023 atoms of hydrogen.
3. 6.022 x 1023 atoms of oxygen.
4. 6.022 x 1023 molecules.
5. (i) and (iii) only.
6. (ii) and (iv) only.
7. (i), (ii) and (iii) only.

(d) (iv) only.

17. Which of the following pairs of solutions, when mixed, would be observed to form a white solid in a green solution?

1. Chromium(III) bromide and potassium chloride.
2. Iron(II) sulfate and sodium carbonate.
3. Copper(II) bromide and silver nitrate.
4. Lead(II) nitrate and nickel sulfate.

18. An empty beaker was placed on an electronic balance. Pieces of tin metal were then added into the beaker and hydrochloric acid was poured over the tin. The initial mass of the beaker and its contents was immediately recorded. Upon completion of the reaction, the mass of the beaker and its contents was again measured, and it was found to have decreased by 1.4 g.

Based on your knowledge of chemistry, which of the following is the most likely explanation for this observation?

1. The reaction produced 1.4 g of CO2(g).
2. The reaction produced 1.4 g of H2(g).
3. The reaction transformed 1.4 g of matter into energy.
4. The chemist realised the balance had not been calibrated properly.

19. Which of the following structures represents the compound 4,4-dibromo-3-methylheptane?

















20. Which of the following species are triangular planar in shape?

1. SO3
2. PF3
3. AlCl3
4. CO32-
5. (i) and (ii) only.
6. (i) and (iii) only.
7. (i) and (iv) only.
8. (iii) and (iv) only.

21. Which of the solutions below would have the highest pH?

1. 0.5 mol L-1 HCl(aq)
2. 0.5 mol L-1 HNO3(aq)
3. 0.5 mol L-1 H2CO3(aq)
4. 0.5 mol L-1 H2SO4(aq)

22. The dichotomous key below can be used to classify the following four (4) substances;

* ice
* carbonic acid solution
* lead(II) iodide suspension
* ammonium oxide powder

Does this substance have a fixed melting point?

Is this substance comprised of discrete molecules?

Can this substance be separated by filtration?

**W**

**X**

**Y**

**Z**

Yes

No

Yes

No

Yes

No

Which of the following correctly identifies substances W and Z?

**W Z**

1. ice carbonic acid solution
2. ammonium oxide powder carbonic acid solution
3. ammonium oxide powder lead(II) iodide suspension
4. ice lead(II) iodide suspension

23. Consider the information provided in the table below.

|  |  |
| --- | --- |
| **Substance** | **Boiling point (°C)** |
| ethanamine | 16.6 |
| ethanal | 20.2 |
| propanone | 56.0 |
| methanol | 64.7 |

Which of the following correctly identifies the substance with the highest vapour pressure, and the substance with the strongest intermolecular forces?

**Highest vapour pressure Strongest intermolecular forces**

1. ethanamine ethanamine
2. ethanamine methanol
3. methanol ethanamine
4. methanol methanol

24. Consider the chemical reaction below.

C2H4(g) + H2(g) → C2H6(g)

Which of the following would **not** increase the rate of this chemical reaction?

1. Decreasing the volume of the reaction vessel.
2. Increasing the temperature of the system.
3. Increasing the state subdivision of the reactants.
4. Adding a nickel catalyst to the reaction mixture.

25. Consider the energy profile diagram below.

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800 –

700 –

600 –

500 –

400 –

300 –

200 –

100 –

Progress of reaction

Enthalpy (kJ mol-1)

The activation energy for this reaction is

(a) 200 kJ mol-1.

(b) 300 kJ mol-1.

(c) 500 kJ mol-1.

(d) 700 kJ mol-1.

**End of Section One**

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**Section Two: Short answer 35% (77 marks)**

This section has 9 questions. Answer **all** questions. Write your answers in the spaces provided.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 60 minutes.

**Question 26 (8 marks)**

A sample of gallium was analysed by mass spectroscopy to determine its isotopic composition.

(a) Identify a **similarity** between the gallium-69 and gallium-71 isotopes in terms of;

1. their atomic structure. (1 mark)

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1. their chemical properties. (1 mark)

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(b) Identify a **difference** between the gallium-69 and gallium-71 isotopes in terms of;

1. their atomic structure. (1 mark)

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1. their physical properties. (1 mark)

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(c) Calculate the relative atomic mass of the gallium in this sample. (1 mark)

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Generally, a sample size of 1 mg is required to perform mass spectrometry.

(d) Calculate the number of atoms present in a 1 mg sample of this gallium. (3 marks)

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**Question 27 (9 marks)**

Consider the period 3 hydrides; silane (SiH4), phosphine (PH3) and hydrogen sulfide (H2S).

(a) Complete the table below, by drawing the Lewis structure and stating the shape of each molecule. (6 marks)

|  |  |  |
| --- | --- | --- |
|  | Lewis structure | Molecular shape |
| SiH4 |  |  |
| PH3 |  |  |
| H2S |  |  |

(b) Identify the most polar compound and justify your choice. (3 marks)

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**Question 28 (7 marks)**

A student compared 1.0 mol L-1 solutions of hydrofluoric acid, HF(aq), and hydrochloric acid, HCl(aq). They found that the electrical conductivity of the HCl(aq) was much higher than that of HF(aq).

(a) Explain the difference in conductivity of these solutions, using relevant chemical equations to support your answer. (5 marks)

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(b) Identify the predominant type of intermolecular force that exists between the solute and solvent in each solution. (2 marks)

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| HF(aq) |  |
| HCl(aq) |  |

**Question 29 (9 marks)**

A student was investigating the reaction between ammonium nitrate powder and potassium hydroxide solution.

(a) Write a balanced ionic equation representing this reaction. Include state symbols in your answer. (2 marks)

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The student set up five (5) test tubes, each containing 1.48 g of ammonium nitrate powder. To each powdered sample, a 25 mL portion of potassium hydroxide was added. However, a different concentration of potassium hydroxide solution was used in each test tube.

The time taken for the powder to dissolve was measured, and the results are summarised in the graph below.

(b) Identify the trend shown in this graph, and explain this trend in terms of the collision theory. (3 marks)

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The potassium hydroxide used in the experiment described above was at room temperature (approximately 25 °C). Consider the effect of repeating the experiment, but warming the potassium hydroxide solution to 40 °C in each trial.

(c) On the graph above, sketch a curve showing the likely results that would be obtained using warm potassium hydroxide. (1 mark)

(d) Explain the shape of your sketched curve, in terms of the collision theory. (3 marks)

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**Question 30 (8 marks)**

Iron is an extremely versatile material, used in many structures such as bridges, cars, ships, railway tracks and reinforced concrete.

Iron(III) oxide is also known as the mineral haematite and is extracted from ores containing this mineral.

(a) Explain, in terms of structure and bonding, why iron is malleable yet iron(III) oxide is brittle. (6 marks)

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(b) Calculate the percentage by mass of iron in iron(III) oxide. (2 marks)

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**Question 31 (9 marks)**

Drinking water supplies are monitored for heavy metals, such as cadmium, which can cause serious health concerns.

(a) Name one (1) other heavy metal. (1 mark)

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Cadmium chloride, CdCl2(s) exhibits a high solubility of 119.6 g per 100 mL of water. A chemist obtained a 245 mL sample of a saturated solution of cadmium chloride.

(b) Define a saturated solution. (2 marks)

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The chemist decided to precipitate the cadmium ions out of the saturated solution, by adding 1.62 mol L-1 aqueous sodium phosphate.

(c) Write a balanced ionic equation for the precipitation reaction that would occur. (2 marks)

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(d) Calculate the minimum volume of sodium phosphate solution required to remove all the cadmium ions from the saturated solution. (4 marks)

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**Question 32 (9 marks)**

A sample of butane was shaken with liquid bromine, in the presence of UV light.

(a) Write a balanced chemical equation for the reaction that would occur. Use structural formulae for all organic compounds. (2 marks)

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A sample of propene was mixed with distilled water, and several drops of concentrated sulfuric acid.

(b) Write a balanced chemical equation for the reaction that would occur. Use structural formulae for all organic compounds. (2 marks)

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(c) What is the function of the UV light in part (a) and the sulfuric acid in part (b)? (1 mark)

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(d) Which of the reactions described in part (a) and (b), would be classified as a substitution reaction? (circle your choice) (1 mark)

(a) **or** (b)

The substitution reaction is an endothermic reaction.

(e) Explain what an endothermic reaction is, in terms of the breaking and forming of bonds. (3 marks)

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**Question 33 (10 marks)**

A chemist poured 18.0 g of water and 18.0 g of liquid nitrogen into separate beakers.

Whilst there were no immediate changes observed for the water, the liquid nitrogen bubbled vigorously, with clouds of white fog forming above the liquid as it vaporised.

(a) Explain, in terms of intermolecular forces, why the boiling point of nitrogen is much lower than that of water. (3 marks)

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The entire contents of each beaker were vaporised and the gases were collected and stored separately, under identical conditions of temperature and pressure.

(b) Identify which gas would occupy the largest volume. Justify your answer. (3 marks)

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The volume of the container storing the nitrogen vapour was halved.

(c) Explain, in terms of the kinetic theory, why the pressure inside the container would increase. (2 marks)

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If the volume of the container storing the nitrogen gas continued to decrease, then liquid nitrogen would eventually reform.

(d) Describe how this observation illustrates the difference between a real gas and an ideal gas. (2 marks)

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**Question 34 (8 marks)**

The unique properties of carbon nanotubes (CNTs) make them a promising material for a variety of applications.

The length of CNTs vary greatly, but can be as long as 1-2 cm.

(a) Why are CNTs classified as nanomaterials? (1 mark)

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(b) Given that bulk carbon is relatively inert, suggest two (2) reasons many countries have guidelines in place to limit people’s exposure to CNTs. (2 marks)

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There are several methods used to synthesise CNTs, one of which involves the use of an iron nanoparticle catalyst.

(c) Describe the economic benefit associated with using catalysts in industry. (2 marks)

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(d) Explain, in terms of collision theory, how a catalyst alters the rate of reaction. (2 marks)

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(e) Identify one (1) way in which an enzyme differs from a metal nanoparticle catalyst. (1 mark)

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**End of Section Two**

**Section Three: Extended answer 40% (88 marks)**

This section contains **five (5)** questions. You must answer **all** questions. Write your answers in the spaces provided below.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 70 minutes.

**Question 35 (19 marks)**

Colour flame candles are a common novelty item at parties. Unlike a regular candle, these candles have been designed so that each produces a different coloured flame when lit.

This is generally achieved by soaking the wicks in different chemicals when the candles are being manufactured. For example, soaking a wick in strontium chloride solution, SrCl2(aq), will produce a red flame. Once the wick is dry, it can be dipped in matching red wax to produce the final candle.

When the candle is lit, a red coloured flame is observed due to the emission spectrum produced by the strontium ions.

(a) Describe how the strontium ions produce an emission spectrum, and why the spectrum emitted is observed as red light. (4 marks)

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(b) Suggest one (1) ethical consideration that the manufacturers of colour flame candles should consider. (1 mark)

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Strontium chloride can be produced from the mineral celestine, which is composed of strontium sulfate, SrSO4(s). The celestine is directly leached with sodium carbonate solution, to produce strontium carbonate, SrCO3(s).

SrSO4(s) + Na2CO3(aq) → SrCO3(s) + Na2SO4(aq)

The strontium carbonate can then be converted to strontium chloride by reacting with hydrochloric acid.

SrCO3(s) + 2 HCl(aq) → SrCl2(aq) + CO2(g) + H2O(l)

A 355 kg sample of pure celestine was converted to strontium carbonate, as described above. The solid strontium carbonate was then dissolved in 925 L of excess hydrochloric acid.

(c) Calculate the maximum concentration of SrCl2(aq) solution produced. (You may assume no change in volume when the strontium carbonate is dissolved in the acid). (4 marks)

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Solid strontium chloride can be obtained from a strontium chloride solution, where it can then be used to produce strontium metal. This can be done on a small scale using electrolysis.

Solid strontium chloride, SrCl2(s), is heated until it becomes molten. At this point, electricity is passed through the liquid, producing strontium metal and chlorine gas. The chemical equation for this process is shown below.

SrCl2(l) → Sr(l) + Cl2(g)

(d) Identify a method that could be used to obtain solid strontium chloride from a strontium chloride solution. (1 mark)

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(e) Explain, in terms of structure and bonding, why strontium chloride can conduct electricity when molten. Use a relevant chemical equation to support your answer. (3 marks)

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Strontium is a highly reactive metal located in group 2 of the Periodic table.

(f) State the name given to the group 2 elements. (1 mark)

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(g) Identify, in terms of atomic structure, the characteristic common to the group 2 elements. (1 mark)

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To the left of strontium on the Periodic table is the metal rubidium.

(h) Explain, by referring to atomic radius, why strontium is more dense than rubidium. (2 marks)

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(i) Explain, by referring to first ionisation energy, why strontium is less reactive than rubidium. (2 marks)

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**Question 36 (18 marks)**

Australia has the third largest reserve of coal in the world, holding about 14% of the global coal supply. Coal is a fossil fuel which has been used as an energy source since ancient times. Even today, coal remains Australia’s largest energy resource.

(a) What is a fossil fuel? (2 marks)

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Burning coal releases pollutants such as sulfur dioxide, nitrous oxides, heavy metals and ash. This is in addition to the large amount of carbon dioxide produced from coal combustion.

Despite Australia’s relatively small population, it ranks 10th in the world for coal consumption.

(b) Identify two (2) reasons that it is **not** desirable for fuels to produce high levels of carbon emissions. (2 marks)

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(c) Identify two (2) reasons that a country may decide to continue to use coal, despite its associated pollution. (2 marks)

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There are four different types of coal, and each has a slightly different chemical composition. The most abundant type of coal is called ‘bituminous coal’, which contains small amounts of sulfur and nitrogen.

The combustion of bituminous coal can be represented by the chemical equation below.

C137H96O9NS(s) + 158 O2(g) → 137 CO2(g) + 48 H2O(g) + SO2(g) + NO(g)

Bituminous coal found in Australia generally has an energy density of 30.4 kJ kg-1.

Note: M(C137H96O9NS) = 1932.208 g mol-1.

(d) Calculate the value of the enthalpy change, in kJ mol-1, associated with this reaction. (4 marks)

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In 2020, Australia consumed 95 985 380 tonnes of bituminous coal, for a population of 25.66 million people.

(e) Calculate the volume of CO2(g), at STP, that was produced **per person** in Australia, due to coal combustion in the year 2020. State your answer to the appropriate number of significant figures. (6 marks)

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Some of the pollutants produced by coal combustion can contribute to the formation of acid rain. For example, sulfur dioxide gas is able to dissolve into atmospheric water producing sulfurous acid. This then leads to rain becoming more acidic.

(f) Write a series of two (2) balanced chemical equations illustrating how the release of sulfur dioxide gas into the atmosphere can lower the pH of rain. (2 marks)

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**Question 37 (16 marks)**

Chromatography was invented in 1900 by the scientist Mikhail Tsvet, who used it primarily in the separation of various plant pigments.

All forms of chromatography involve the use of both a mobile and a stationary phase in order to separate the components of a mixture.

(a) Describe the basic principles of chromatography, with reference to how these two phases allow separation to occur. (3 marks)

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In 1952, Archer Martin and Richard Synge were awarded the Nobel prize in Chemistry for their revolutionary work in chromatography. One of the techniques they developed was two-dimensional chromatography, which was used to achieve a much better separation of amino acid mixtures than had previously been possible.

The following method describes how two-dimensional thin layer chromatography (TLC) can be performed, resulting in the separation of amino acids.

Note: the amino acids are labelled with their three-letter abbreviations in the diagrams below. Use these abbreviations to answer subsequent questions, where required.

**X**

mixture of 10 different amino acids

**Step 1:**

The mixture of amino acids is spotted onto the TLC plate at position X.

**Step 2:**

The TLC plate is placed in solvent 1 and initial separation of the amino acids is allowed to occur.

**Step 3:**

The TLC plate is completely dried, before being rotated 90° anticlockwise.

**X**

solvent front 1

**Step 4:**

The TLC plate is placed in solvent 2. Further separation of the amino acids then occurs.

**Step 5:** The TLC plate is sprayed with ninhydrin, resulting in the amino acid spots turning brown and thus being visible.

**Step 6:** Retention factors can then be calculated, and amino acids identified.

**X**

solvent front 1

7.0 cm

6.0 cm

5.0 cm

4.0 cm

3.0 cm

2.0 cm

1. cm

0.0 cm

**X**

solvent front 1

solvent front 2

7.0 cm

6.0 cm

5.0 cm

4.0 cm

3.0 cm

2.0 cm

1. cm

0.0 cm

Trp

Val

Cys

Pro

Ala

Met

Gly

Thr

Arg

Lys

Val

Cys

Met

Trp

Ala

Pro

Gly

Thr

Arg

Lys

The TLC process above used ‘normal phase’ chromatography, where the stationary phase is polar. Solvent 1 was composed of predominantly non-polar substances.

(b) Based on the appearance of the TLC plate upon completion of Step 2, identify the least polar amino acid. Justify your answer, by referring to the intermolecular forces involved. (3 marks)

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Before the development of two-dimensional chromatography, amino acids were difficult to separate and identify. Compare the appearance of the TLC plate upon completion of Step 2 and Step 4.

(c) Describe an advantage of two-dimensional chromatography over traditional one-dimensional chromatography, in the separation of amino acids. (2 marks)

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An unknown amino acid was analysed using identical conditions to those described in the method above. The retention factor (Rf) values for this amino acid were calculated and are given in the table below.

|  |  |  |
| --- | --- | --- |
|  | Solvent 1 | Solvent 2 |
| Rf | 0.61 | 0.43 |

(d) Determine the most likely identity of this amino acid. Show your working. (2 marks)

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One of the advantages of TLC is that a wide range of solvents can be used as the mobile phase. Some common solvents used in TLC are named in the table below.

(e) Complete the following table, by drawing the structural formula of each compound. Show all atoms and bonds. (3 marks)

|  |  |
| --- | --- |
| **Solvent** | **Structural formula** |
| pentane |  |
| trichloromethane |  |
| benzene |  |

(f) Identify the most polar solvent in the table in part (e). (1 mark)

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When developing new analytical techniques, as Martin and Synge did, it is important that these methods are both valid and reliable.

(g) Define ‘validity’. (1 mark)

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(h) Identify one way to ensure a scientific method is reliable. (1 mark)

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**Question 38 (16 marks)**

A chemistry student placed a small mass of zinc carbonate **chips** into test tube A, which contained excess nitric acid. The following chemical reaction took place;

ZnCO3(s) + 2 HNO3(aq) → Zn(NO3)2(aq) + CO2(g) + H2O(l)

The student then decided to repeat the experiment by placing **powdered** zinc carbonate into test tube B, which also contained excess nitric acid. The student’s aim was to investigate the effect of reactant subdivision on the reaction rate.

(a) Identify three (3) variables the student should control, in order to ensure a valid comparison. (3 marks)

|  |  |
| --- | --- |
| 1 |  |
| 2 |  |
| 3 |  |

(b) Identify two (2) ways in which the observations for the powdered solid would have differed from the solid chips. (2 marks)

|  |  |
| --- | --- |
| 1 |  |
| 2 |  |

(c) Explain, in terms of collision theory, why the observations were different for test tube A and test tube B. (3 marks)

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The gas produced in this reaction is carbon dioxide, CO2(g), which is often identified in the laboratory using the ‘limewater test’. In this test, a sample of gas is bubbled through a solution of limewater, Ca(OH)2(aq). If the colour of the limewater turns a milky white, the presence of CO2(g) is confirmed.

The milky white appearance is due to the formation of solid calcium carbonate particles, forming a suspension. The chemical equation occurring in the limewater test is given below.

Ca(OH)2(aq) + CO2(g) → CaCO3(s) + H2O(l)

The student weighed out 1.04 g of powdered ZnCO3(s), and again placed it into a test tube containing excess nitric acid. All of the CO2(g) evolved was bubbled through a sample of limewater, where only 15.0% of the gas dissolved. The final mass of the limewater suspension was 29.1 g.

(d) Calculate the concentration of CaCO3(s), in parts per million, in the resulting limewater suspension. (You may assume no change in volume when carbon dioxide is dissolved in the limewater). (8 marks)

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**Question 39 (19 marks)**

The diamond company De Beers have used the phrase ‘A Diamond is Forever’ in their advertising campaign since 1948. However, interestingly, the conversion of diamond into graphite is known to occur via a spontaneous process, which can be represented as follows;

C(s, diamond) → C(s, graphite)

As can be seen in the chemical equation above, both forms of carbon have the same chemical formula.

(a) State the name given to structurally different forms of the same element. (1 mark)

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Both forms of carbon also have very high melting points.

(b) Explain, in terms of structure and bonding, why this is so. (3 marks)

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There are, however, some properties which diamond and graphite do not share. For example, diamond is unable to conduct electricity whereas graphite can.

(c) Explain, in terms of structure and bonding, the difference in conductivity. (4 marks)

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Whilst the conversion of diamond to graphite is spontaneous, it has an extremely high activation energy of 370 kJ mol1-. The difference in enthalpy of diamond and graphite is quite small however, with diamond having 1.9 kJ mol-1 greater enthalpy than graphite.

(d) On the axes below, sketch an energy profile diagram for the conversion of diamond to graphite. Label the activation energy and enthalpy change. (5 marks)

Enthalpy (kJ mol-1)

Progress of reaction

Without the application of extremely high heat and pressure, diamond takes billions of years to turn into graphite.

(e) Suggest a likely reason for this. (1 mark)

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Diamonds used in jewellery are typically measured in carats, where 1 carat is equal to a mass of 200 mg. Consider the process of converting a 0.77 carat diamond into graphite.

(f) Calculate the quantity of heat energy absorbed or released during this process. Clearly state in your answer whether heat energy is absorbed or released. (5 marks)

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**End of questions**

**Additional working space**

Question number(s): ……………………

**Additional working space**

Spare grid Q39 (d)

Enthalpy (kJ mol-1)

Progress of reaction

**Additional working space**

Question number(s): ……………………

**Additional working space**

Question number(s): ……………………

**Additional working space**

Question number(s): ……………………

WATP acknowledges the permission of the School Curriculum and Assessment Authority in providing instructions to students.