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**Insert School Logo**

**CHEMISTRY**

**UNITS 1&2**

**2021**

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

Teacher: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

# Time allowed for this paper

## Reading time before commencing work: ten minutes

Working time: 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 (blue/black preferred), pencils (including coloured), sharpener,

eraser, correction tape/fluid, ruler, highlighters

Special items: up to three calculators, which do not have the capacity to create or store programmes or text, are permitted in this ATAR course examination

# 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 material. 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 examination |
| Section One  Multiple-choice | 25 | 25 | 50 | / 25 | / 25 |
| Section Two  Short answer | 10 | 10 | 60 | / 80 | / 35 |
| Section Three  Extended answer | 5 | 5 | 70 | / 88 | / 40 |
|  | | | | | / 100 |

**Instructions to candidates**

1. Write your answers in this Question/Answer booklet preferably using a blue/black pen. Do not use erasable or gel pens.

2. 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. Do not use erasable or gel pens. 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.

3. When calculating numerical answers, show your working or reasoning clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

4. 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.

5. 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.

6. The Chemistry Data Book is not to be 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. Do not use erasable or gel pens. 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.

1. Which of the following statements regarding an atom of neon-20 is correct?

1. The atomic number is 20.
2. The mass number is 20.
3. The number of neutrons is 20.
4. The number of electrons is 20.

2. Consider the balanced chemical equation below.

2 H2(g) + O2(g) → 2 H2­O(g)

Which of the following statements is **not** correct?

1. The total number of atoms in the reactants must equal the total number of atoms in the products.
2. The total number of molecules of reactants must equal the total number of molecules of products.
3. The total mass of hydrogen within the reactants must equal the total mass of hydrogen within the products.
4. The total number of moles of oxygen within the reactants must equal the total number of moles of oxygen within the products.

3. Which of the formulae in the table below correctly match the names given?

|  |  |  |
| --- | --- | --- |
|  | Name | Formula |
| (i) | dinitrogen tetroxide | N2O4 |
| (ii) | strontium nitrite | SrNO2 |
| (iii) | lithium hydrogenphosphate | Li2HPO4 |
| (iv) | iron(III) cyanide | Fe2(CN)3 |
| (v) | sodium oxalate | Na2O |

1. (i) and (iv) only.
2. (ii) and (iii) only.
3. (i) and (iii) only.
4. (ii) and (v) only.

4. The aqueous solubility of a particular solute is being investigated. As the temperature of the water decreases, the solubility of the solute would likely **increase** if the solute

(a) was a gas.

(b) was a solid.

(c) was polar.

(d) was non-polar.

5. Which of the following properties is **not** common to both diamond and graphite?

1. Covalent network bonding
2. Inert
3. High melting point
4. Hard

**Questions 6 and 7 relate to the information provided in the table below.**

|  |  |  |
| --- | --- | --- |
|  | Surface tension at 20 °C (mN m-1) | Boiling point (°C) |
| water, H2O | 72.80 | 100.0 |
| methanol, CH3OH | 22.70 | 64.65 |

6. The surface tension of water is greater than that of methanol because

1. water has stronger intermolecular forces.
2. water has a higher molar mass.
3. water has a higher boiling point.
4. water has a greater volatility.

7. When measured at the same temperature, the vapour pressure would be greater for

1. water, because it has covalent bonds.
2. water, because it has a higher boiling point.
3. methanol, because it has hydrogen bonding.
4. methanol, because it has weaker intermolecular forces.

8. Which of the following statements is/are correct for particles in the transition state of a chemical reaction?

1. They can quickly form reactants.
2. They can quickly form products.
3. They have maximum enthalpy.
4. (ii) only.
5. (i) and (ii) only.
6. (ii) and (iii) only.
7. All of (i), (ii) and (iii).

**Questions 9, 10 and 11 relate to the information provided in the partially completed table below.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Symbol | Number of protons | Number of neutrons | Number of electrons |
| V |  |  | 11 |  |
| W |  | 15 | 15 | 15 |
| X | + | 11 |  |  |
| Y | 3- |  |  | 18 |
| Z |  | 13 |  | 10 |

9. Which two species are isotopes?

1. V and X.
2. W and Y.
3. X and Z.
4. V and Z.

10. Which two species have the same electron configuration?

1. V and X.
2. W and Y.
3. X and Z.
4. V and Z.

11. The radius of

1. V is less than that of W.
2. X is less than that of Z.
3. Y is less than that of W.
4. X is less than that of V.

12. Consider the chemical reaction below.

2 SO2(g) + O2(g) → 2 SO3(g)

Which of the following changes would **not** increase the rate of reaction?

1. Increasing the concentration of SO2(g) in the system.
2. Increasing the volume of the system.
3. Increasing the temperature of the system.
4. Adding an appropriate catalyst to the system.

13. The semi-structural formula of 4,4-dimethylpent-2-ene is

1. (CH3)3CCH2CHCH2
2. CH3C(CH3)2CH(CH3)CH3
3. CH3CHCHC(CH3)2CH3
4. CH3CH2CH(CH3)CH(CH3)CH3

14. Which of the following statements regarding the kinetic theory of gases shows **least** correlation with the behaviour of a real gas?

(a) The particles of a gas move in random straight-line motion.

(b) The particles of a gas occupy no volume.

(c) The average distance between gas particles is very large compared to the size of the particles.

(d) The average kinetic energy of gas particles increases with increasing temperature.

**Questions 15 and 16 relate to the information below.**

Four (4) beakers labelled W, X, Y and Z, were known to contain the following 0.5 mol L-1 solutions; Na2S(aq), K2CO3(aq), ZnCl2(aq) and Pb(NO3)2(aq).

In order to find the identity of the solutions, samples were taken from each of the beakers and mixed. The table below shows which samples were mixed, as well as the corresponding observations.

|  |  |  |  |
| --- | --- | --- | --- |
|  | W | X | Y |
| X | white solid formed |  |  |
| Y | white solid formed | no visible reaction |  |
| Z | white solid formed | white solid formed | grey solid formed |

15. The formula of the grey solid produced when samples from beakers Y and Z were mixed is

1. Pb(NO3)2.
2. PbCl2.
3. PbCO3.
4. PbS.

16. The results in the table demonstrate that ZnCl2(aq) was in beaker

1. W.
2. X.
3. Y.

(d) Z.

17. A sample of juice was being analysed by high-performance liquid chromatography (HPLC) to confirm whether citric acid was present. Subsequently, the results of the analysis were compared to a calibration curve to determine the concentration of citric acid in the juice.

In order for the data to be reliable, the HPLC conditions used for the citric acid analysis must be the same as those used to produce the citric acid calibration curve. These are referred to as ‘controlled variables’.

Which of the following is **not** a variable that needs to be controlled in this investigation?

1. The stationary phase.
2. The mobile phase.
3. The pressure applied.
4. The amount of sample loaded.

18. The electron configuration of potassium is

1. 2, 8, 9
2. 2, 8, 8, 1
3. 2, 8, 8, 21
4. 2, 8, 18, 11

19. Activation energy is the

1. minimum amount of energy released in a chemical reaction.
2. maximum amount of energy released in a chemical reaction.
3. minimum amount of energy required for a chemical reaction to occur.
4. maximum amount of energy required for a chemical reaction to occur.

20. Metacresol purple is a pH indicator exhibiting three (3) different colours, as shown in the diagram below.

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

pH

|  |  |  |  |
| --- | --- | --- | --- |
|  | red | yellow | purple |

Which of the solutions below would be **least** likely to turn yellow, when several drops of metacresol purple are added to it?

(a) H2O(l)

(b) NH3(aq)

(c) NaCl (aq)

(d) CH3COOH(aq)

21. Which of the organic substances below would exhibit dipole-dipole forces but **not** hydrogen bonding between molecules in a pure sample?

|  |  |
| --- | --- |
| (i) |  |
| (ii) |  |
| (iii) |  |
| (iv) |  |
| (v) |  |

1. (i) and (v) only.
2. (ii) and (iv) only.
3. (ii), (iii) and (v) only.
4. (ii), (iv) and (v) only.

22. Consider the relationships between the pressure and volume of a gas, and the volume and temperature of a gas.

Which of the following correctly defines these relationships as being ‘directly’ or ‘indirectly’ proportional?

**Pressure and volume Volume and temperature**

1. indirectly proportional directly proportional
2. indirectly proportional indirectly proportional
3. directly proportional directly proportional
4. directly proportional indirectly proportional

**Questions 23 and 24 refer to the following three (3) organic reactions.**

1. CH3CHCHCH3 + H2O → **X**
2. CH3CH3 + **Y** → CH2ClCH3 + HCl
3. CH3CH2CH2Br + NaOH → CH3CH2CH2OH + **Z**

23. Which of the following options correctly identifies substances X, Y and Z?

**X Y Z**

1. CH3CH2CHOHCH3 Cl2 NaBr
2. CH3CHOHCH2CH3 HCl NaBr
3. CH3CHOHCH2CH3 Cl2 HBr
4. CH3CH2CH2CH2OH HCl Br2

24. Which of these would be classified as a substitution reaction?

(a) (i) only.

(b) (ii) only.

(c) (i) and (iii) only.

(d) (ii) and (iii) only.

25. Which of the following gases is likely to have the lowest concentration in a well-functioning catalytic converter?

1. CO2(g)
2. NO2(g)
3. H2O(g)
4. N2(g)

**End of Section One**

**Section Two: Short answer 35% (80 marks)**

This section has **ten (10)** 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)**

When solid potassium nitrate is added to water at room temperature, the solid quickly dissolves according to the following equation;

KNO3(s) → K+(aq) + NO3-(aq)

This process can be represented by the energy profile diagram below.

KNO3(s)

K+(aq) + NO3-(aq)

Progress of reaction

Potential energy (kJ mol-1)

(a) Identify the type of bonds that are being broken and formed in this process. (3 marks)

|  |  |
| --- | --- |
| Bonds broken |  |
| Bonds formed |  |

(b) Relate the energy involved in these bond breaking and bond forming processes to the enthalpy change of the reaction. (3 marks)

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(c) Predict, with justification, whether the activation energy for this reaction is likely to be high or low. (2 marks)

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**Question 27 (8 marks)**

Complete the table below, by stating the name of the substance that matches each description.

|  |  |
| --- | --- |
| Description | Name |
| The chemical with the formula KMnO4(s). |  |
| The chemical with the formula H2SO3(aq). |  |
| The substance with the structural formula |  |
| The element in group 10, period 6. |  |
| A species with 16 protons and 18 electrons. |  |
| A black solid containing silver ions. |  |
| The substance formed by the reaction of propene and hydrogen chloride. |  |
| The solid formed when Ba(NO3)2(aq) and Na2SO4(aq) are mixed. |  |

**Question 28 (7 marks)**

Consider the information in the table below, regarding the boiling points of two silicon-containing species.

|  |  |
| --- | --- |
| Compound | Boiling point (°C) |
| Silane, SiH4 | -111.9 |
| Silica, SiO2 | 2950 |

(a) Explain, in terms of structure and bonding, the difference in boiling points of these two substances. (5 marks)

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(b) Which of these compounds contains the higher percent by mass of silicon? Calculate this value. (2 marks)

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**Question 29 (7 marks)**

Four (4) chemical reactions were set up in separate test tubes, according to the table below.

|  |  |
| --- | --- |
| Test tube A | Hydrochloric acid solution and cobalt metal. |
| Test tube B | Aqueous sodium hydroxide and nitric acid solution. |
| Test tube C | Aqueous potassium hydroxide and ammonium chloride powder. |
| Test tube D | Hydrochloric acid solution and magnesium carbonate powder. |

(a) In which test tube (A, B, C or D) would a gas **not** be produced? (1 mark)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(b) Write a balanced ionic equation for the reaction occurring in the test tube where a pungent-smelling gas is produced. (2 marks)

|  |
| --- |
|  |

(c) Write observations for the reaction occurring in test tube D. (2 marks)

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(d) Write a balanced ionic equation for the reaction occurring in the test tube where a pink solution is formed. (2 marks)

|  |
| --- |
|  |

**Question 30 (9 marks)**

Consider the three sulfur-containing substances in the following table.

|  |  |  |
| --- | --- | --- |
|  | Lewis diagram | Name of shape |
| carbon disulfide,  CS2 |  |  |
| sulfur dioxide,  SO2 |  |  |
| thiophosgene,  CSCl2 |  |  |

(a) Complete the table above by;

* drawing a Lewis diagram for each substance, representing all electron pairs as either : or –, and
* stating the shape of the molecule. (6 marks)

(b) Predict which of these substances would have the lowest solubility in water. Explain your answer in terms of intermolecular forces. (3 marks)

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**Question 31 (8 marks)**

An ore deposit was found to contain high levels of a naturally occurring alloy. The alloy was examined by various methods, in order to obtain information regarding its composition and properties.

Physical analysis of the alloy found that it was malleable and ductile.

(a) Explain these properties in terms of structure and bonding. (3 marks)

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A sample of the alloy was analysed by mass spectroscopy to determine its composition. The results are displayed below.

One of the component metals was identified to be copper.

(b) Name the other two (2) metals that comprise the alloy. (2 marks)

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

A water sample, taken from a lake near the ore deposit, was analysed by flame test to determine whether any copper was present. A characteristic blue-green flame was observed, suggesting a considerable concentration of copper ions had leached into the lake.

(c) Briefly explain, in terms of electron behaviour, how this blue-green light was produced by the copper ions. (3 marks)

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**Question 32 (8 marks)**

Consider the information in the graph below, regarding the conductivity of three different aqueous solutions.

(a) Explain, in terms of structure and bonding, the difference between the conductivity of each of these solutions. (6 marks)

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(b) Predict, with justification, whether the conductivity of distilled water would be higher, lower or the same as that of tap water. (2 marks)

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**Question 33 (8 marks)**

Phosphorus pentachloride reacts with water to produce a mixture of phosphoric and hydrochloric acids, as shown in the chemical equation below.

PCl5(s) + 4 H2O(l) → H3PO4(aq) + 5 HCl(aq)

(a) Describe why both the products of this reaction are classified as ‘acids’ according to the Arrhenius theory. (1 mark)

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(b) Define a ‘weak’ acid, and identify which of the products is classified as weak. (2 marks)

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(c) Define a ‘monoprotic’ acid, and identify which of the products is classified as monoprotic. (2 marks)

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(d) If 17.8 g of phosphorus pentachloride was dissolved in 345 mL of water, calculate the concentration of hydrochloric acid in the resulting solution. (3 marks)

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**Question 34 (9 marks)**

Thin layer chromatography (TLC) can be used to detect the presence of preservatives in different cosmetics. A glass plate coated in polar silica gel is used as the stationary phase. The mobile phase is a benzene-acetone (8:2) mixture.

(a) Complete the following table regarding the components of the mobile phase. (3 marks)

|  |  |  |
| --- | --- | --- |
|  | Benzene | Acetone |
| Structural diagram |  |  |
| ‘Polar’ or ‘non-polar’ substance |  |  |

Using the conditions described above, several preservatives were analysed by TLC. Once separated, the preservatives were visualised by UV detection. The retention factor values were calculated using the formula;

Retention factor (Rf) = distance travelled by component

distance travelled by solvent

The results of this analysis are provided in the table below.

|  |  |
| --- | --- |
| Preservative | Rf |
| Dichlorophene | 0.50 |
| Fluorosan | 0.56 |
| Hexachlorophene | 0.14 |
| Salicylanilide | 0.65 |
| Tribromsalan | 0.60 |
| Chlorhexidine acetate | 0.40 |
| Phenylphenol | 0.68 |

(b) Which of these preservatives is the most polar? Justify your answer. (4 marks)

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Three cosmetic products; shampoo, deodorant and hand soap; were then analysed by TLC under identical conditions. A diagram of the resultant TLC plate is provided below.

*origin*

*solvent front*

X

X

X

8 cm

7 cm

6 cm

5 cm

4 cm

3 cm

2 cm

1 cm

0 cm

8 cm

7 cm

6 cm

5 cm

4 cm

3 cm

2 cm

1 cm

0 cm

shampoo

deodorant

hand soap

(c) Which cosmetic product is most likely to contain tribromsalan? (1 mark)

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(d) Give one (1) reason that it cannot be known for certain that tribromsalan is in this cosmetic product. (1 mark)

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**Question 35 (8 marks)**

Hydrogen peroxide is a colourless solution which decomposes into water and oxygen gas under standard laboratory conditions.

The enthalpy change for this reaction is given as; DH = -196 kJ mol-1 of hydrogen peroxide.

(a) Write a balanced thermochemical equation representing this reaction. (3 marks)

|  |
| --- |
|  |

(b) Suggest one (1) method for measuring the rate of this reaction. (1 mark)

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The rate of this reaction can be greatly enhanced by adding some solid manganese(IV) oxide catalyst to the hydrogen peroxide solution. The activation energy, in the presence of the catalyst, is 23 kJ mol-1.

(c) On the axes below, sketch an energy profile diagram for the catalysed reaction. Label the enthalpy change and the activation energy. (3 marks)

Progress of reaction

Potential energy (kJ mol-1)

(d) Suggest one (1) method, not related to the manganese(IV) oxide catalyst, that would further increase the rate of this reaction. (1 mark)

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**End of Section Two**

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**Section Three: Extended answer 40% (87 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 and include appropriate units where applicable.

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 36 (17 marks)**

The Sabatier process was developed in 1897 by the French chemist Paul Sabatier. In this reaction, carbon dioxide and hydrogen gas are converted to methane and water vapour as shown in the chemical equation below.

CO2(g) + 4 H2(g) → CH4(g) + 2 H2O(g)

The Sabatier process is conducted at a temperature of approximately 400 °C and a pressure of 30 atmospheres (i.e. 30 times atmospheric pressure).

(a) Explain, in terms of the collision theory, why using a high pressure and a high temperature increase the rate of the reaction. (4 marks)

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Much of Sabatier’s groundbreaking work focused on the mechanisms of catalysis. Whilst there are now several different metal catalysts routinely used in the Sabatier process, the original catalyst was nickel metal.

(b) Explain, in terms of the collision theory, how the inclusion of a metal catalyst increases the rate of this reaction. (2 marks)

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In 1912, Sabatier won the Nobel Prize for Chemistry for the discoveries he had made regarding the use of **finely divided** catalysts. Today, ongoing research into the role of metal nanoparticle catalysts is providing exciting advancements in many areas of chemistry.

(c) Define a nanoparticle. (1 mark)

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(d) Explain, in terms of collision theory, the advantage of using nickel in nanoparticle form compared to bulk nickel. (2 marks)

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The Sabatier process is used by NASA on board the International Space Station, to produce water for the crew. The chemical equation for the Sabatier process is provided again below, for convenience.

CO2(g) + 4 H2(g) → CH4(g) + 2 H2O(g)

The carbon dioxide exhaled by the astronauts is collected and reacted with hydrogen gas that forms as a by-product of a different on-board reaction. The water vapour is cooled and condensed into a liquid. This produces 2495 kg of water each year.

(e) Calculate the total mass of carbon dioxide that must be exhaled by the astronauts each year, in order to produce this mass of water. State your answer to the appropriate number of significant figures. (5 marks)

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The crew of astronauts on the International Space Station each exhale, on average, 1.303 kg of carbon dioxide per day.

(f) Determine how many astronauts are likely to be on board the International Space Station at any one time. Show any relevant workings. (3 marks)

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**Question 37 (19 marks)**

Floatation tanks (float tanks, sensory deprivation tanks) are lightless, soundproof tanks containing a salt solution which is dense enough to enable the user to float. Float tanks are said to provide benefits such as relaxation and pain relief, as well as improved sleep, circulation and immunity.

Float tanks contain around 1000 L of salt solution. This solution contains a very high concentration of Epsom salts, MgSO4.7H2O(s), which is maintained at 35 °C. The resulting MgSO4(aq) solution is designed to be just under saturation point. If too little salt is added, the solution will not be dense enough to allow the user to float. If too much salt is added, crystals of solute form and may block water filtering equipment.

(a) Distinguish between a saturated and an unsaturated solution. (2 marks)

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A particular float tank company prepared a tank containing 1000 L of salt solution. This solution had a density of 1.27 kg L-1 and was known to be composed of 30.0% MgSO4 by mass.

(b) Calculate the concentration of the MgSO4(aq) solution in moles per litre. (5 marks)

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(c) Calculate the mass of Epsom salts, MgSO4.7H2O(s), that would have been dissolved to produce this solution. (2 marks)

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The solubility of MgSO4.7H2O(s) at 35 °C is known to be 113 g per 100 mL.

(d) Prove that this float solution is unsaturated. Show all workings. (3 marks)

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To ensure that health and safety standards are upheld, the salt solution used in float tanks is periodically treated with chemicals such as chlorine, bromine or UV light.

(e) Suggest two (2) reasons these treatments may be performed on the salt solution. (2 marks)

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The float tank company decided to use bromine, Br2(l), to treat the salt solution described above. Industry guidelines state that the concentration of bromine must be maintained at 6 ppm.

(f) Calculate the mass of bromine that should be present in 1000 L of salt solution. (2 marks)

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The pH of the salt solution must also be monitored and should fall between 6.8 and 7.6.

(g) What is the pH scale? (1 mark)

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(h) Suggest two (2) reasons the pH should be maintained at this level. (2 marks)

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**Question 38 (16 marks)**

Bioethanol is a widely used fuel in countries such as Brazil, the U.S. and Sweden. Bioethanol is chemically identical to ethanol, but it is produced from the fermentation of corn or sugar cane.

In the initial steps of the process, the sugars in these materials are broken down into glucose molecules. Yeast enzymes, such as *zymase*, are then mixed with the glucose solution to undergo fermentation. This produces ethanol and carbon dioxide gas, as shown in the chemical equation below.

C6H12O6(aq) 2 C2H5OH(aq) + 2 CO2(g)

(a) Justify why ethanol manufactured in this way is classed as a ‘biofuel’. (1 mark)

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(b) Explain why the overall carbon emissions from bioethanol are lower than those from ethanol produced from crude oil. (2 marks)

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The fermentation process would not be possible without the presence of the enzyme catalysts found in yeast.

(c) Identify three (3) features of an enzyme, that are different to an inorganic catalyst. These may be structural or functional features. (3 marks)

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The ethanol produced by fermentation can be removed from the reaction mixture and concentrated to a pure liquid, by distillation.

(d) Describe the principles of distillation as a separation technique. (2 marks)

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Bioethanol, like all fuels, can be combusted to produce heat energy. The products of combustion are different depending on the quantity of oxygen gas present. The chemical equations below illustrate the combustion of ethanol in both plentiful and limited oxygen environments.

Excess oxygen: C2H5OH(l) + 3 O2(g) → 2 CO2(g) + 3 H2O(g) + 1371 kJ

Limited oxygen: 2 C2H5OH(l) + 3 O2(g) → 2 CO(g) + 2 C(s) + 6 H2O(g) + 1117 kJ

A 288 g sample of ethanol was combusted in the presence of **excess** oxygen. The gaseous products from the combustion of the ethanol were collected, and the temperature and pressure conditions were adjusted to STP. This resulted in one of the products condensing into a liquid.

(e) Identify the remaining gaseous product and calculate the volume it would occupy. (4 marks)

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(f) Calculate the energy released in this process. (1 mark)

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(g) Calculate the mass of ethanol that would be required to produce the same amount of energy if combustion had been carried out in a **limited** oxygen environment. (3 marks)

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**Question 39 (20 marks)**

Hexane is a colourless, odourless organic solvent. It is a significant component of petrol and is also used as a cleaning agent in furniture and shoe factories.

The term ‘*hexanes*’ refers to a mixture of hexane isomers. Isomers are substances that have the same molecular formula but different structures. A mixture of *hexanes* is predominantly composed of hexane, but may also contain isomers such as 2-methylpentane and 2,3-dimethylbutane. *Hexanes* is much cheaper and is used in situations where pure hexane is not necessary.

A sample of *hexanes* was known to contain the three (3) compounds in the table below.

|  |  |  |
| --- | --- | --- |
| Component | Semi-structural diagram | Boiling point (°C) |
| hexane |  | 69.0 |
| 2-methylpentane |  | 63.3 |
| 2,3-dimethylbutane |  | 58.0 |

(a) Identify the predominant intermolecular force acting in a solution of *hexanes*. Justify your answer. (2 marks)

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(b) Explain, in terms of intermolecular forces, the different boiling points of these three isomers. (3 marks)

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A chemist had two unlabelled bottles on their laboratory bench. One contained *hexanes*, whilst the other contained pure hexane.

A sample was taken from each bottle and analysed by gas chromatography (GC). The samples were analysed separately, but under identical conditions. The two chromatograms below were obtained.

Chromatogram A Chromatogram B

l l l l l

0.5 1.0 1.5 2.0 2.5

Retention time (mins)

Absorbance units

X

.

l l l l l

0.5 1.0 1.5 2.0 2.5

Retention time (mins)

Absorbance units

X

.

Y

.

Z

.

(c) Which chromatogram corresponds to *hexanes* and which to hexane? Justify your answer. (3 marks)

|  |  |
| --- | --- |
|  | Chromatogram (A or B) |
| *hexanes* |  |
| hexane |  |

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(d) Identify the compound represented by peak X. Justify why this peak is higher on chromatogram A than B. (3 marks)

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(e) Identify the compounds represented by peaks Y and Z. (2 marks)

|  |  |
| --- | --- |
| Y |  |
| Z |  |

Exposure to high levels of hexane has been known to cause vertigo, fatigue, headaches and drowsiness. Therefore, the concentration of hexane in air must be monitored in order to ensure the health and safety of factory workers who may inhale this compound. The recommended exposure limit for hexane is 50 ppm over an 8 hour work day.

The air in a particular furniture factory was known to contain 50 ppm hexane. On average, a factory worker takes 15 breaths per minute, and each breath has a volume of 0.50 L. The density of air was measured to be 1.225 g L-1.

(f) Calculate the number of hexane **molecules** that would be inhaled by a factory worker during an 8 hour work day. (8 marks)

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**Question 40 (15 marks)**

The first periodic table of the elements was designed by the Russian chemist Dmitri Mendeleev, and was published in 1869. The periodic table arranges the elements according to recurring trends.

The seven rows of the periodic table are called periods. Consider the elements in period 3, as shown below.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Na | Mg | Al | Si | P | S | Cl | Ar |

(a) Describe why these elements are all located in period 3. (1 mark)

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As you move from left to right across period 3, both the first ionisation energy and electronegativity of the elements increase.

(b) Define ‘first ionisation energy’ and ‘electronegativity’, and explain the increasing trend observed in each. (5 marks)

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Now consider the *chlorides* of the period 3 elements;

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| NaCl | MgCl2 | AlCl3 | SiCl4 | PCl3 | SCl2 | Cl2 |

The first three of these chloride compounds are considered to exhibit ionic bonding, whilst the latter four are classified as covalent compounds.

(c) Use the concepts of ionisation energy and electronegativity to explain why NaCl is an ionic substance, whilst Cl2 is a covalent substance. (4 marks)

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(d) Explain why Cl2 is the only one of these covalent compounds to contain non-polar bonds. (2 marks)

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(e) Explain why SiCl4 is classified as a non-polar molecule, despite containing polar bonds. Include the Lewis structure of SiCl4 in your answer. (3 marks)

|  |
| --- |
| Lewis structure: |

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**End of questions**

Spare answer page

Question number: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_