

EX-WACE EXAM QUESTIONS

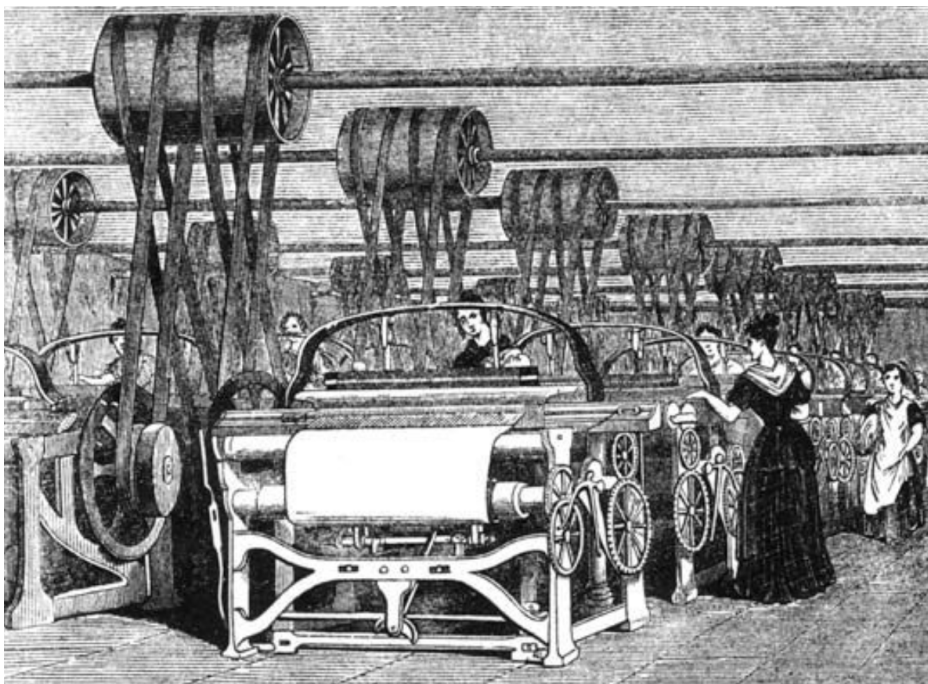
SCIENTIFIC METHODS

+

REACTION RATES & CHEMICAL EQUILIBRIUM

in

INDUSTRIAL PROCESSES



Questions 22 to 25 refer to the following information.

Some chemistry students were investigating the relationship between concentration and rate of reaction. In the investigation, different concentrations of hydrochloric acid were added to a sodium thiosulfate solution to produce solid sulfur. This reaction was represented by the following equation.



A piece of paper with a cross drawn on it was placed under the reaction vessel. The time taken for the cross to disappear due to the formation of the precipitate was measured.

22. The independent variable was the
- (a) time taken for the cross to disappear.
 - (b) total volume of the mixture.
 - (c) rate of reaction.
 - (d) concentration of hydrochloric acid.
23. The type of data collected and the source of data are best characterised as
- (a) qualitative and primary.
 - (b) qualitative and secondary.
 - (c) quantitative and primary.
 - (d) quantitative and secondary.
24. When a number of laboratory groups pooled their data, one group's results were consistently higher than those of the others. This is an example of
- (a) a systematic error.
 - (b) not enough trials.
 - (c) a random error.
 - (d) uncertainty.
25. One group chose to have its members take turns observing and timing the cross disappearing. This was poor methodology because
- (a) it could make the data invalid.
 - (b) it introduced a possible systematic error.
 - (c) more trials would be needed to produce better results.
 - (d) the data would be less reliable.

End of Section One

See next page

Section One: Multiple-choice

25% (25 Marks)

Question No.	Answer
22	D
23	C
24	A
25	D

Question 30

(8 marks)

Carbonyl chloride, COCl_2 , is a colourless, poisonous gas that is used in the production of insecticides and a variety of plastics. It is produced through the exothermic reaction between carbon monoxide and chlorine gases. Carbonyl chloride is a liquid below 8°C at 100.0 kPa.

The following equation is used to represent the reaction.



- (a) For this industrial process state the conditions that would optimise the: (2 marks)

rate of reaction _____

yield _____

- (b) State **one** compromise in conditions that might be required to produce carbonyl chloride, COCl_2 , in an industrial process. Explain the effect of this condition on the rate and yield and justify why this compromise is required. (6 marks)

Question 30

(8 marks)

- (a) For this industrial process state the conditions that would optimise the: (2 marks)
rate of reaction
yield

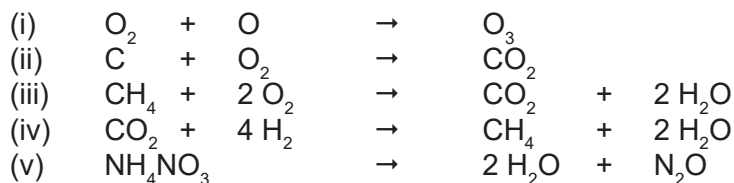
Description	Marks
Rate: high temperature, high pressure, catalyst Note: At least two conditions must be given	1
Yield: low temperature, high pressure/maintain high concentration of reactants; removal of products Note: At least two conditions must be given	1
Total	2
Note: If one incorrect condition - no marks.	

- (b) State **one** compromise in conditions that might be required to produce carbonyl chloride, COCl_2 , in an industrial process. Explain the effect of this condition on the rate and yield and justify why this compromise is required. (6 marks)

Description	Marks
One condition requiring a compromise is the temperature at which the process occurs.	1
A high temperature is required to maximise the rate of reaction because a greater proportion of particles will: <ul style="list-style-type: none">• be moving faster and so collide more frequently and• have sufficient energy (greater than the activation energy, E_a) resulting in a greater proportion of successful collisions.	1–2
A low temperature is required (to maximise the yield of COCl_2) because: <ul style="list-style-type: none">• the reaction is exothermic in the forward direction, lowering the temperature favours the forward reaction• products are formed at a higher rate than reactants are formed.	1–2
Higher temperatures favour a higher rate but with a reduced yield while lower temperatures favour a higher yield but at a reduced rate. (A compromise of a moderate temperature is required to produce reasonable yield at a reasonable rate.)	1
Total	6

12. The United Nations Kyoto Protocol and the Intergovernmental Panel on Climate Change aim to secure a global commitment to reducing greenhouse gas emissions over the next few decades.

Which of the following equations shows the production of a greenhouse gas?



- (a) i and ii only
 (b) ii and iii only
 (c) iii, iv and v only
 (d) i, ii, iii, iv and v
16. Chemists must act ethically when conducting research. Which of the following statements relate to **ethical** behaviour?
- (i) Chemists calibrate all of their instruments with primary standards.
 (ii) Chemists give due credit to all contributors to an investigation in their written reports.
 (iii) Chemists record their experimental results accurately and without alteration to fit their prediction.
 (iv) Chemists dispose of their waste materials carefully, especially those containing heavy metals.
 (v) Chemists ensure that there is only one independent variable in every experiment they perform.
 (vi) Chemists declare any conflict of interest relevant to their investigation.
- (a) i, ii and iii only
 (b) ii, iv and v only
 (c) ii, iii, iv and vi only
 (d) i, iii, iv, v and vi only

The following information relates to Questions 19, 20

A group of Year 12 Chemistry students wanted to know whether increasing ocean acidity increases the rate at which sea shells, CaCO_3 , dissolve. They went to a beach to collect seawater and sea shells. In their school laboratory they crushed the sea shells and added 2.00 g of the resulting powder to five clean 250 mL beakers, each of which had been placed on top of its own electronic balance.

They split the seawater into five portions and bubbled carbon dioxide gas into four of the portions for different amounts of time. This gave the students 'natural' seawater plus four seawater samples of different pH. The various seawaters (150 mL portions) were then added to the beakers, with the weight of each beaker and its contents being recorded at timed intervals.

19. Which one of the following proposes a suitable hypothesis for the investigation?
- (a) As the seawater becomes more acidic, the sea shell powder will dissolve faster.
 - (b) The sea shell powder will dissolve fastest in the most acidic seawater.
 - (c) Adding carbon dioxide to seawater changes the pH of the seawater.
 - (d) More of the sea shell powder will dissolve as time progresses.
20. Which one of the following pairs of statements on the validity and reliability of the investigation is correct?

	Validity	Reliability
(a)	It is valid because the investigation allows them to determine if seawater pH affects the rate of sea shell dissolution.	It is reliable because the trials were performed in a laboratory.
(b)	It is not valid because the investigation was simulated in a laboratory and not performed in a real ocean.	It is not reliable because only one trial was performed at each different pH value.
(c)	It is not valid because the investigation was simulated in a laboratory and not performed in a real ocean.	It is reliable because trials were performed at five different pH values.
(d)	It is valid because the investigation allows them to determine if seawater pH affects the rate of sea shell dissolution.	Its reliability could be improved by conducting multiple trials at each different pH value.

Section One: Multiple-choice

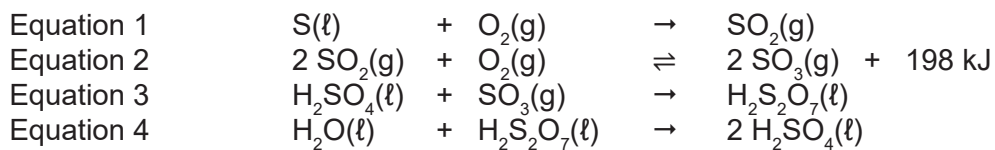
25% (25 Marks)

Question No.	Answer
12	d
16	c
19	a
20	d

Question 29

(8 marks)

Sulfuric acid is a very useful chemical that is produced industrially by a multi-stepped process. These steps are summarised by the following equations.



When dihydrogen sulfate, $\text{H}_2\text{SO}_4(\ell)$, is mixed with water, it produces sulfuric acid, $\text{H}_2\text{SO}_4(\text{aq})$.

- (a) Combine these equations to produce an overall equation for the production of dihydrogen sulfate, $\text{H}_2\text{SO}_4(\ell)$, from sulfur dioxide, $\text{SO}_2(\text{g})$. (2 marks)

- (b) Complete the following table by listing the advantages and disadvantages of using high temperatures and high pressures for the reaction represented by Equation 2 above. Consider yield, rate, cost and safety. (6 marks)

	Advantage/s	Disadvantage/s
High temperature		
High pressure		

Question 29

(8 marks)

- (a) Combine these equations to produce an overall equation for the production of dihydrogen sulfate, $\text{H}_2\text{SO}_4(\ell)$, from sulfur dioxide, $\text{SO}_2(\text{g})$. (2 marks)

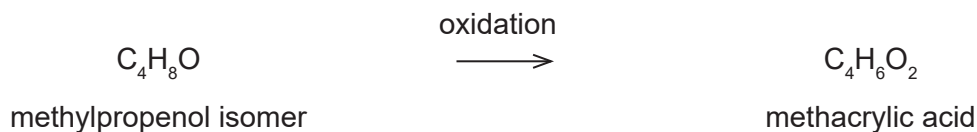
Description	Marks
One mark for correct products and reactants	1
One mark for correct balancing	1
Total	2
Example of a two mark response: $2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) + 2 \text{H}_2\text{O}(\ell) \rightleftharpoons 2 \text{H}_2\text{SO}_4(\ell)$	

- (b) Complete the following table by listing the advantages and disadvantages of using high temperatures and high pressures for the reaction represented by Equation 2 above. Consider yield, rate, cost and safety. (6 marks)

Description	Marks
High Temperature	
Advantage increase rate	1
Disadvantages two of: decrease yield, high energy cost or high safety hazards, (more) expensive	1–2
High Pressure	
Advantages increase rate	1
increase yield	1
Disadvantage high cost (of construction and maintaining pressure) or high safety hazards	1
Total	6
Note: <ul style="list-style-type: none"> The answers may be expressed in different ways but must clearly indicate these understandings. No explanation required. 	

Question 38

One method for the production of methacrylic acid is by the following oxidation.



- (d) Suggest an assumption that **must** be made regarding the mole ratios of product to reactant for this reaction and then determine the mass of the methylpropenol isomer required to produce 1.50 tonne of methacrylic acid if the efficiency of this oxidation is 65%. (Note: 1 tonne = 1000 kg.) (5 marks)

Assumption: _____

Calculation: _____

- (d) Suggest an assumption that **must** be made regarding mole ratios of product to reactant for this reaction and then determine the mass of the methylpropenol isomer required to produce 1.50 tonne of methacrylic acid if the efficiency of this oxidation is 65%.
(Note: 1 tonne = 1000 kg.) (5 marks)

Description	Marks
Assumption: $n(\text{C}_4\text{H}_8\text{O}) = n(\text{C}_4\text{H}_6\text{O}_2)$	1
Calculation:	
$n(\text{C}_4\text{H}_6\text{O}_2) = 1.50 \times 10^6 / 86.088$ $= 1.742 \times 10^4 \text{ mol}$	1
$m(\text{C}_4\text{H}_8\text{O}) = 72.104 \times 1.742 \times 10^4$ $= 1.256 \times 10^6 \text{ g}$ represents 65% efficiency	1
$m(\text{C}_4\text{H}_8\text{O}) = 100/65 \times 1.256 \times 10^6$ $= 1.93 \times 10^6 \text{ g}$ represents 100% efficiency	1
Correct molar masses	1
Total	5

Question 36

(17 marks)

A scientist was given the task of investigating the concentration of dissolved heavy metals in abandoned open-cut mines that had filled with water to create small freshwater dams.

Using a map, the scientist identified 180 locations containing abandoned open-cut mines that had become freshwater dams. The scientist decided to randomly select locations to take water samples. The procedure for water sampling at each location was as follows:

1. Take two samples using separate 100.0 mL bottles at a water depth of 0.50 m.
2. Acidify each sample with a few drops of nitric acid solution to minimise heavy metal precipitation.
3. Wait eight hours before measuring heavy metal concentration.
4. Calculate the average concentration of a range of heavy metals, using two samples per location.

- (a) Outline the difference between random and systematic errors. Give an example of each that might be encountered in this investigation. (4 marks)

Water samples were collected from 59 of the 180 possible locations.

- (b) (i) Calculate the sample size as a percentage of the testable locations. (1 mark)

- (ii) Propose **two** reasons why samples were not collected from all locations. (2 marks)

One: _____

Two: _____

- (iii) Predict the effect of using a smaller sample size on the reliability of the overall results. Justify your answer. (2 marks)

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Question 36

(17 marks)

- (a) Outline the difference between random and systematic errors. Give an example of each that might be encountered in this investigation. (4 marks)

Description	Marks
Random errors are fluctuations in measured data due to limitations of the measurement device/technique, they occur unpredictably and to varying extents throughout the experiment. Non-directional effect on results.	1
Examples <ul style="list-style-type: none"> concentration of heavy metals may vary at depth judgement made by the sample collector about depth different collectors at different sites 	1
Systematic errors are repeatable errors that occur due to faulty equipment or poor experiment design, they occur consistently to the same extent throughout the experiment. Results are skewed in one direction.	1
Examples <ul style="list-style-type: none"> faulty timer concentration of the nitric acid may not be exactly the same as labelled water bottles and whether or not 100 mL is marked accurately on them (glassware uncertainty). 	1
Total	4

Water samples were collected from 59 of the 180 possible locations.

- (b) (i) Calculate the sample size as a percentage of the testable locations. (1 mark)

Description	Marks
sample size = $(59/180) \times 100 = 32.8 \%$	1
Total	1

- (ii) Propose **two** reasons why samples were not collected from all locations. (2 marks)

Description	Marks
<ul style="list-style-type: none"> too expensive too time consuming accessibility sample size deemed to be sufficient (statistical) 	1–2
Total	2

Note: reason to be related to the context of the investigation

- (iii) Predict the effect of using a smaller sample size on the reliability of the overall results. Justify your answer. (2 marks)

Description	Marks
Prediction: less reliable	1
Justification: <ul style="list-style-type: none"> smaller sample size means less locations sampled which means less chance of collecting samples with the full range of heavy metal concentrations or <ul style="list-style-type: none"> Increases the effect of random errors 	1
Total	2

(18 marks)

SpaceX plans to solve this problem by using the Sabatier reaction. The equation for the reaction is:



- temperature of 300 – 400 °C
- pressure of 200 – 300 kPa
- nickel catalyst.

(a) With reference to rates of reaction, equilibrium and economic considerations, explain why the above conditions are considered optimal for the Sabatier reaction. In your response, address any compromises in conditions. (7 marks)

This image shows a single sheet of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There are approximately 20 lines visible. The paper has a slight shadow on the right side, suggesting it's resting on a surface.

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Question 38 (continued)

- (b) Predict the effect of each of the following changes on the methane yield in the Sabatier reaction. (5 marks)

Imposed change	Effect on methane yield (circle your answer)		
a suitable catalyst is added	increase	decrease	no effect
the volume of the reaction vessel is increased	increase	decrease	no effect
the temperature is increased	increase	decrease	no effect
methane is removed through a special valve as soon as it forms	increase	decrease	no effect
the partial pressure of carbon dioxide is decreased	increase	decrease	no effect

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Question 38

(18 marks)

- (a) With reference to rates of reaction, equilibrium and economic considerations, explain why the above conditions are considered optimal for the Sabatier reaction. In your response, address any compromises in conditions. (7 marks)

Description	Marks
Temperature <ul style="list-style-type: none"> high temperature gives a fast rate of reaction reaction is exothermic so a low temperature increases the product yield so temperature conditions to maximise rate and yield are opposite therefore a compromise is needed. hence the moderate temperature of (300 – 400 °C) that is used 	1–3
Pressure <ul style="list-style-type: none"> high pressure increases the rate of the reaction in this reaction high pressure increases the product yield 	1–2
Economics <ul style="list-style-type: none"> using high temperatures and pressures increases the operating costs (high energy requirements, cost of specialised equipment) 	1
<ul style="list-style-type: none"> use of catalyst which increases the reaction rate, means lower pressures and temperatures can be used to achieve reasonable reaction rates, improving the economics of the process 	1
Total	7

- (b) Predict the effect of each of the following changes on the methane yield in the Sabatier reaction. (5 marks)

Description	Marks
<ul style="list-style-type: none"> a suitable catalyst is added 	no effect 1
<ul style="list-style-type: none"> the volume of the reaction vessel is increased 	decrease 1
<ul style="list-style-type: none"> the temperature is increased 	decrease 1
<ul style="list-style-type: none"> methane is removed through a special valve as soon as it forms 	increase 1
<ul style="list-style-type: none"> the partial pressure of carbon dioxide is decreased 	decrease 1
Total	5

Imposed change	Effect on methane yield (circle your answer)		
a suitable catalyst is added	increase	decrease	no effect
the volume of the reaction vessel is increased	increase	decrease	no effect
the temperature is increased	increase	decrease	no effect
methane is removed through a special valve as soon as it forms	increase	decrease	no effect
the partial pressure of carbon dioxide is decreased	increase	decrease	no effect

Question 32

(13 marks)

Some students were asked to identify the 'best' cleaning solvent for the removal of graffiti from concrete. They were given black spray paint and five different cleaning solvents.

The students sprayed five different 10 cm by 10 cm areas of a concrete wall with the black paint and allowed the paint to dry for 24 hours. They then used 100 mL of cleaning solvent to try to remove the black paint, with a different cleaning solvent being used for each square. The students subsequently ranked the cleaning solvents from 1 to 5 based on their ability to dissolve the black paint with 1 being the best and 5 being the worst.

The results of the students' investigation, plus some information about the composition of each cleaning solvent, are shown in the table below.

Solvent	Investigation ranking	Composition of cleaning solvent
distilled water	5	water
turpentine	2	straight-chain hydrocarbons containing ten carbon atoms and one double bond
acetone	3	propanone
white spirit	1	straight-chain hydrocarbons C7 to C12
methyated spirits	4	5% methanol, 95% ethanol

- (a) Identify the independent and dependent variables in the students' investigation. (2 marks)

Independent variable	
Dependent variable	

- (b) State **two** variables that the students needed to control in their investigation. (2 marks)

One: _____

Two: _____

(c) What could the students do to ensure that their investigation was:

(i) valid? (1 mark)

(ii) reliable? (1 mark)

(d) Identify **two** safety risks associated with the students' investigation and state how each risk could be minimised. (4 marks)

Safety risk	How to minimise the risk

(e) Paints contain, among other things, a pigment (which is the paint colour) and a solvent (which dissolves the pigment). When paint dries, the solvent evaporates, leaving the pigment behind.

Use this information, the students' results and your knowledge of chemistry to identify the predominant type of intermolecular force occurring between the pigment molecules in the black paint used by the students. Explain your reasoning. (3 marks)

Question 32

(13 marks)

- (a) Identify the independent and dependent variables in the students' investigation. (2 marks)

Description	Marks
Independent variable = identity of the (cleaning) solvent	1
Dependent variable = the amount/extent to which the black spray paint is dissolved/removed	1
Total	2

- (b) State **two** variables that the students needed to control in their investigation. (2 marks)

Description	Marks
Identification of one variable that needs to be controlled.	1
Identification of another (different) variable that needs to be controlled.	1
Total	2
Answers could include: <ul style="list-style-type: none"> the brand of black spray paint the concrete/wall the paint is sprayed on thickness of paint drying temperature size of the painted areas drying time volume of cleaning solvent used method used to apply the cleaning solvent. 	

- (c) What could the students do to ensure that their investigation was: (2 marks)

- (i) valid?

Description	Marks
To make their investigation valid they will need to (either) <ul style="list-style-type: none"> design/perform an investigation that compares the effectiveness of different cleaning solvents on the removal of black spray paint from concrete. ensure the control variables are controlled. 	1
Total	1

- (ii) reliable?

Description	Marks
To make their investigation reliable they will need to repeat their investigation several times (if they obtain consistent/reproducible results then their investigation is reliable).	1
Total	1

Question 32 (continued)

- (d) Identify **two** safety risks associated with the students' investigation and state how each risk could be minimised. (4 marks)

Description	Marks
Identification of one safety risk	1
States how to minimise that risk	1
Identification of another (different) safety risk	1
States how to minimise that risk	1
Total	4
Answers could include: <ul style="list-style-type: none"> chemicals contacting the eyes, wear safety glasses inhalation of fumes, wear suitable mask chemicals contacting skin on hands, wear safety gloves spilling chemicals on feet, wear enclosed shoes spilling chemicals on exposed skin, wear enclosed shoes/gloves and/or lab coat. 	
Note: <ul style="list-style-type: none"> The risk must be a plausible risk for the investigation detailed in the question. For full marks the minimising strategy must match the risk. If only minimising risk box is filled in, 0 marks. 	

- (e) Paints contain, among other things, a pigment (which is the paint colour) and a solvent (which dissolves the pigment). When paint dries, the solvent evaporates, leaving the pigment behind.

Use this information, the students' results and your knowledge of chemistry to determine the predominant type of intermolecular force occurring between the pigment molecules in the black paint used by the students. Explain your reasoning. (3 marks)

Description	Marks
The paint's pigment molecules must have dispersion forces as their predominant intermolecular force because the best solvents have dispersion forces as their predominant intermolecular force.	1
<ul style="list-style-type: none"> This is because for substances to be soluble in each other they must be able to disrupt the existing intermolecular forces and form new intermolecular forces with each other. This can only be done if the intermolecular forces are of similar strength (hence they all need dispersion forces as their predominant intermolecular force). 	1–2
Total	3