CRANBROOK SCHOOL

Centre Number

Student Number

2015

HSC Term 2 Examination

Assessment Task 3

Task Weighting 15%

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 2 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- Use the Data Sheet and Periodic Table provided
- Use the Multiple-Choice Answer Sheet provided
- Write your Centre Number and Student Number at the top of this page, the Multiple-Choice Answer Sheet, and on the booklet for Section II.
- **Section II** is answered in the booklet.

Total marks – 67

This paper has two Sections, Section I and Section II

Section I (55 marks)

Part A – 20 marks
- Attempt Questions 1-20
- Allow about 35 minutes for this part

Part B – 35 marks
- Attempt Questions 21-27
- Allow about 65 minutes for this part

Section II (12 marks)
- Attempt Question 28 in a booklet
- Allow about 20 minutes for this part

This paper must not be removed from the examination room

Disclaimer
The content and format of this paper does not necessarily reflect the content and format of the HSC examination paper.

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2015 YEAR 12 MID-YEAR EXAMINATION
CHEMISTRY

Part A – 20 marks
Attempt Questions 1-20
Allow about 35 minutes for this part

Use the multiple-choice answer sheet provided for Questions 1-20

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

Sample 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A○ B● C○ D○

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

A● B⊗ C○ D○

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

correct

A⊗ B⊗ ← C○ D○

1 An unknown chemical was extracted from a soil sample and sent to your laboratory. One of the first tests you carried out was to determine the pH of the chemical by using indicators. The results were:

Indicator	***Colour***
Phenolphthalein	Colourless
Methyl orange	Yellow
Bromothymol blue	Yellow

How should your laboratory classify the chemical from the soil sample?

(A) neutral

(B) slightly alkaline

(C) highly acidic

(D) slightly acidic

2 Identify the CORRECT statement.

(A) Metals tend to form acidic oxides, which react with bases.

(B) Non-metals tend to form acidic oxides, which produce aqueous solutions of low pH.

(C) Non-metals tend to form basic oxides, which react with water to produce acids.

(D) Non-metals tend to form oxides which will neutralise acids.

3 An acidic, pollutant gas formed during high temperature combustion in air is:

(A) nitrogen monoxide.

(B) nitrogen dioxide.

(C) carbon monoxide.

(D) ammonia.

4 According to the Lavoisier's acid theory, an acid is a substance which:

(A) contains oxygen atoms.

(B) turns blue litmus red.

(C) is neutralised by a base.

(D) is capable of donating a proton.

5 Which of the following species does NOT contain a co-ordinate covalent bond?

(A) O_3

(B) H_3O^+

(C) NH_3

(D) NH_4^+

6 Which of the following lists the CORRECT combination of alcohols and acids used to form an ester?

	Acid	Alcohol	Ester
(A)	pentanoic	ethanol	pentyl ethanoate
(B)	butanoic	1-propanol	1-propyl butanoate
(C)	ethanoic	methanol	methyl methanoate
(D)	methanoic	methanol	ethyl methanoate

7 A bright, apple-green flame was observed when a flame test was performed on a white solid. Adding a small amount of the white solid to 2.0M HCl solution produced bubbles of a colourless gas.

From these results it is possible to conclude that the unknown solution contained :

(A) nickel and chloride ions.

(B) copper and sulfate ions.

(C) barium and carbonate ions.

(D) copper and carbonate ions.

8 The pH of a sulfuric acid solution is measured at 2.0 by a pH meter.

Which of the following alternatives shows the correct concentrations of hydrogen and sulfate ions in this solution?

	Concentration of hydrogen ions in solution (M)	Concentration of sulfate ions in solution (M)
A	1.0×10^{-1}	2.0×10^{-1}
B	1.0×10^{-2}	2.0×10^{-2}
C	1.0×10^{-1}	5.0×10^{-2}
D	1.0×10^{-2}	5.0×10^{-3}

9 A group of 5 students collected a large bottle of water from a river. Each student evaporated a 100 mL aliquot of the river water to determine the total solids per 100 mL. Their results are tabulated below.

Student number	***Mass in grams per 100 mL***
1	0.696
2	0.701
3	0.705
4	0.598
5	0.698

The students needed to calculate an average mass/100 mL to determine the total solids in the river. Which value should the students use?

(A) 0.6796

(B) 0.680

(C) 0.700

(D) 0.7

10 The table below shows the solubility of carbon dioxide in water at various temperatures.

Temperature (°C)	***Solubility (g of CO_2 per 100 g water)***
0	0.320
10	0.220
20	0.170
30	0.130
40	0.095

Use Le Chatelier's Principle and the data in the table to determine which is the correct statement.

(A) $CO_2\ (g) \rightleftharpoons CO_2\ (aq)$ is endothermic

(B) $CO_2\ (g) \rightleftharpoons CO_2\ (aq)$ is exothermic

(C) $CO_2\ (g) \rightarrow CO_2\ (aq)$ is endothermic

(D) $CO_2\ (aq) \rightarrow CO_2\ (g)$ is endothermic

11 Identify the CORRECT statement about the isomers of $C_2F_3Cl_3$.

(A) There are three isomers: 1,1,1-trichloro-2,2,2-trifluoroethane, 1,2,2-trichloro-1,1,2-trifluoroethane and 1,1,2-trichloro-1,2,2-trifluoroethane.

(B) There are two isomers: 1,1,1-trichloro-2,2,2-trifluoroethane, and 1,1,2-trichloro-1,2,2-trifluoroethane.

(C) There are two isomers: 1,1,1-trifluoro-2,2,2-trichloroethane, and 1,1,2-trifluoro-1,2,2-trichloroethane.

(D) There are three isomers: 1,1,1-trifluoro-2,2,2-trichloroethane, 1,2,2-trifluoro-1,1,2-trichloroethane and 1,1,2-trifluoro-1,2,2-trichloroethane.

12 Which of the following lists contains substances which are in order of increasing boiling points?

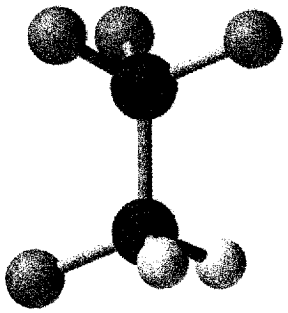
(A) ethanol, ethene, ethane

(B) methanol, ethane, propanol

(C) propanol, ethanol, methanol

(D) methane, methanol, methanoic acid

13 Consider the structural formula shown below.



HFC-134a, CH_2FCF_3

Which of the following is the **systematic name** for this compound?

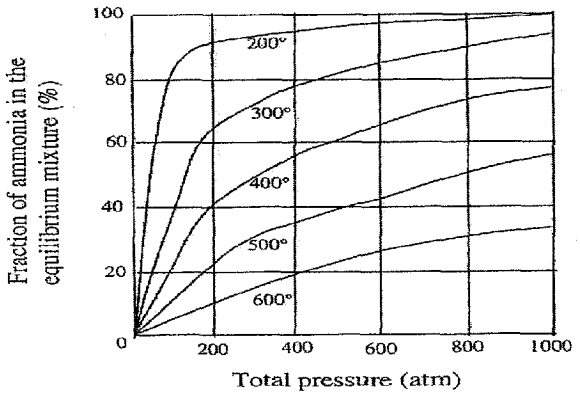
(A) 1,1,2-trifluoromethane.

(B) 1,1,2-trifluoroethane.

(C) 1,1,1,2-tetrafluoromethane.

(D) 1,1,1,2-tetrafluoroethane.

14 The graphs below show the fraction of ammonia present at equilibrium when nitrogen and hydrogen react under varying conditions of temperature and pressure.



Use the information from the graphs above to identify the conditions of temperature and pressure which would give the highest yield of ammonia.

(A) 600°C and 1000atm.

(B) 200°C and 150atm.

(C) 600°C and 150atm.

(D) 200°C and 1000atm.

15 Incomplete combustion of petrol may result in the production of undesirable pollutants.

Two such pollutants produced from the incomplete combustion of petrol are:

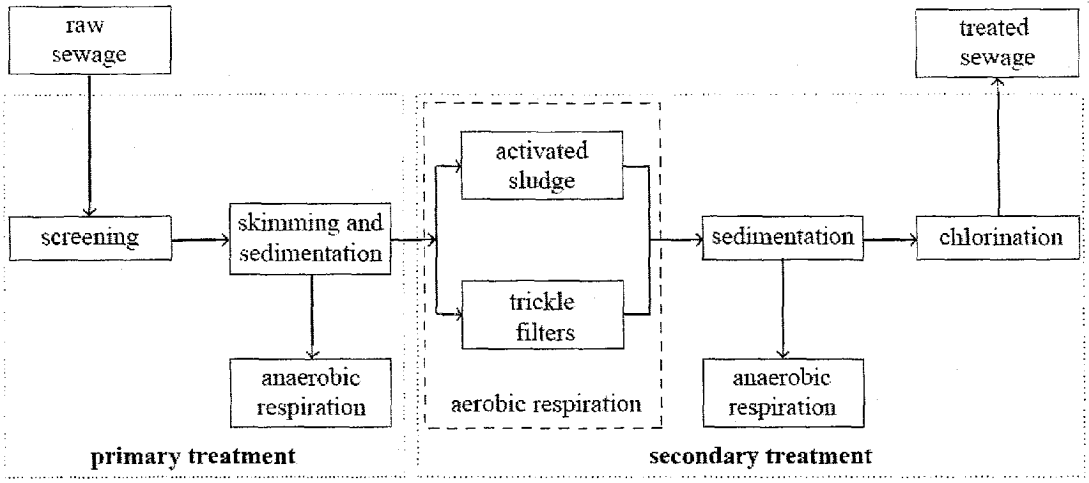
(A) carbon and carbon monoxide.

(B) carbon and carbon dioxide.

(C) carbon dioxide and water.

(D) nitrogen oxides and carbon monoxide.

16 A schematic diagram representing the processes used at a small sewage treatment plant is shown below.



Two water samples from this sewage plant were tested for the biochemical demand (BOD). The following results were obtained:

Water sample	*BOD ($mg\ L^{-1}$)*
1	1.2
2	2500

These results indicate that:

(A) sample 1 is treated sewage while sample 2 is raw sewage.

(B) both samples were taken from the primary treatment plant.

(C) sample 2 has more than 2000 times the dissolved oxygen of sample 1.

(D) both samples were taken from the secondary treatment plant.

17 The onset of eutrophication of a river system can be predicted by high levels of:

(A) dead and decaying plants and animals.

(B) BOD readings.

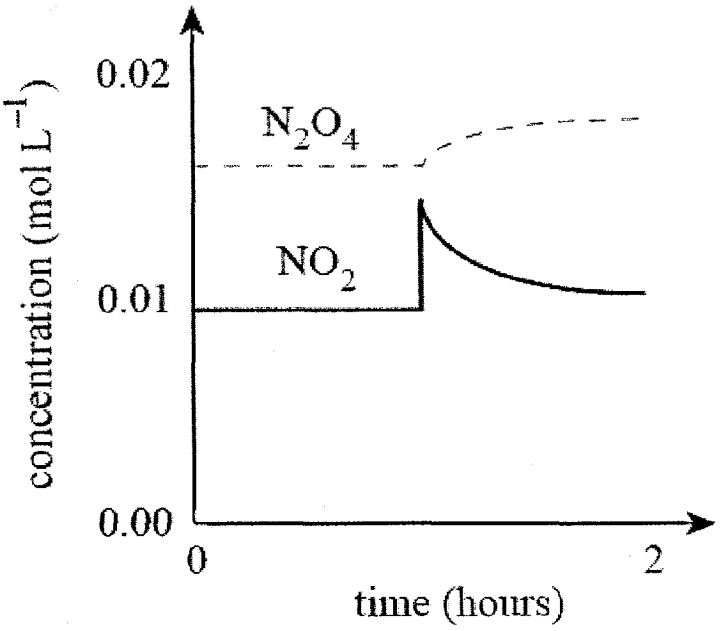
(C) nutrients, especially phosphate and nitrate ions.

(D) turbidity.

18 The decomposition of dinitrogen tetroxide (N_2O_4) is represented by the following equilibrium equation:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = 58 \text{ kJ mol}^{-1}$$

The graph below shows this equilibrium system undergoing a disturbance and shifting to re-establish a new equilibrium.



The disturbance shown in the above graph was caused by

(A) a decrease in pressure.

(B) an increase in temperature.

(C) the addition of some NO_2 gas.

(D) the removal of some NO_2 gas.

19 Modern refrigerators no longer contain CFCs. A suitable non-CFC refrigerant which does not cause ANY destruction of ozone in the stratosphere is

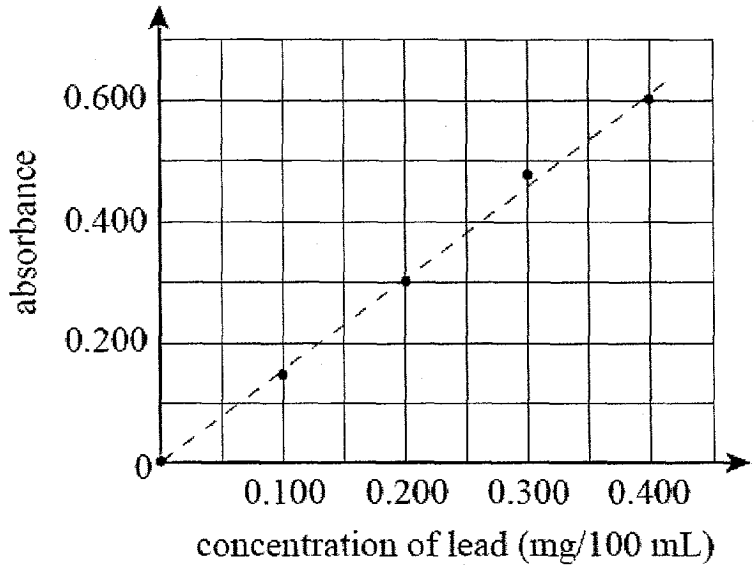
(A) tetrafluoromethane.

(B) 1-chloro-1-fluoroethane.

(C) trichlorofluoromethane.

(D) 1,1,2,2-tetrachloro-1-fluoroethane.

20 A chemist analysed a sample of soil for lead contamination. A 10.0 g sample of soil was treated with a mixture of nitric and hydrochloric acids to dissolve all the lead in the soil sample. The resulting solution was diluted to 1.00 L and the concentration of lead was determined using AAS. The absorbance of a series of lead standard solutions was measured and the results plotted to give the graph below.



The absorbance of the 1.00 L soil sample was found to be 0.200. The concentration, in ppm, of lead in the soil sample is:

(A) 0.130

(B) 13.0

(C) 130

(D) 300

Chemistry

Student Number

Part B – 35 marks
Attempt Questions 21-27
Allow about 65 minutes for this part

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

Question 21 (3 marks)

A student was provided with two colourless solutions, each in a separate beaker, labelled X and Y. They were informed that one solution was 0.10M hydrochloric acid, the other 0.10M ethanoic acid.

The student performed two tests on the solutions:

Test 1: The pH was determined by inserting a pH probe into each solution.

Test 2: The volume of 0.10M sodium hydroxide solution needed to reach end-point with the acids was determined with a suitable indicator.

Compare the effectiveness of the two tests in determining the identity of each acid. Justify your answer.

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Marks

Question 22 (4 marks)

The daily recommended intake for Vitamin C (ascorbic acid) is 60 mg.

The label on a brand of orange juice claims the juice contains over half the daily requirement of Vitamin C (ascorbic acid) in every 100 mL of the juice.

The concentration of ascorbic acid in juice can be determined by titration method. A sample of juice is titrated against a standard solution of iodine using starch as an indicator.

The following reaction takes place as the iodine is added to the juice sample:

$$C_6H_8O_6\ (aq) + I_2\ (aq) \rightarrow 2I^-\ (aq) + C_6H_6O_6\ (aq) + 2H^+\ (aq)$$

The starch remains colourless as the iodine is added until all of the ascorbic acid present has reacted with the iodine. As soon as any excess iodine is present, a blue-black colour is observed, as the starch reacts with the iodine. This is the end-point of the titration.

In an experiment to determine the vitamin C content in the above juice, a 25.0 mL sample of juice was added to a conical flask, along with 5 drops of starch solution. This sample was titrated with 5.00×10^{-3} mol/L iodine solution. An average of 9.15 mL of iodine was needed to reach end-point.

(a) Identify the piece of glassware which would be used to accurately deliver 25mL of orange juice into conical flask. **1**

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(b) Calculate the mass (in mg) of ascorbic acid present in the 25 mL sample of orange juice. Show your working **2**

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(c) Determine if the claim made on the label of the juice is valid. Show your working. **1**

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Marks

Question 23 (4 marks)

The sleepy little town of Snug has a river flowing through it, which begins in the nearby mountains and discharges into an ocean bay. The town has a poor quality sewage treatment plant, and a large area of agricultural land.

The following data were collected at various places along the river.

Site	Dissolved O_2 (ppm)	BOD (ppm)	pH	$[NO_3^-]$ (ppm)	$[Cl^-]$ (ppm)
A	9	1	6.9	0.1	50
B	8	2	6.8	3.3	62
C	3	16	5.2	3.8	10,000

(a) Identify the site closest to the source of the river, justifying your answer. **2**

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(b) Justify the locals' decision not to swim in the bay near the mouth of the river. **2**

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Question 24 (5 marks)

Ammonia production has remained one of the most important processes since its industrialization in 1913.

Explain how the conditions used in the process maximize rate and yield, and assess the importance of the catalyst.

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Question 25 (6 marks) **Marks**

Lead is regarded as a heavy metal. The levels of lead in soil and water supplies need to be monitored as lead has been found to be detrimental to health.

(a) Describe how lead ions in a sample can be identified in a laboratory using precipitation reactions. Write equations for the reactions you describe. **3**

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(b) Assess the effectiveness of atomic absorption spectroscopy (AAS) and precipitation reactions as methods for detection of lead ions in water or soil samples. **3**

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Question 26 (7 marks) **Marks**

A student prepared an ester by heating methanol and propanoic acid, using concentrated sulfuric acid as a catalyst under reflux.

(a) Name the ester formed. **1**

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(b) Draw an expanded structural formula for this ester. **1**

(c) Draw the structure of an acid which is an isomer of the ester you have drawn in part (b) above. **1**

(d) Justify TWO reasons for the use of heating under reflux during this experiment. **2**

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Question 26 continues on the next page

Question 26 (continued)

(e) Explain why the boiling point of an ester is lower than the boiling points of acids or alcohols of similar molar mass. **2**

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Question 27 (6 marks) **Marks**

A student was interested in confirming the sulfate content of a lawn-food, so he carried out the following investigation.

1. Weigh a 250 mL beaker.
2. Add two spatulas of lawn-food and reweigh the beaker with lawn-food.
3. Add 100 mL of 0.1M HCl and stir the mixture.
4. Add 50 mL of saturated $BaCl_2(aq)$.
5. Filter to obtain the precipitate using a pre-weighed filter paper.
6. Wash the precipitate and dry for 10 minutes.
7. Reweigh the filter paper and precipitate.

He also recorded the following observations and results during the experiment.

- The lawn-food appeared to be an uneven, grey colour.
- Even though I stirred the lawn-food with the acid for a few minutes, not all of it dissolved.
- When I added the $BaCl_2$ solution, a dense, white precipitate formed suddenly.
- My teacher told me to expect the filtration not to work very well, but none of the solid went through my filter paper into the filtrate.

Results:

- Mass of beaker: 305.5 g
- Mass of beaker and lawn-food: 306.9 g
- Mass of filter paper: 0.105 g
- Mass of filter paper + precipitate: 1.425 g.

(a) Write the net ionic equation for the reaction that occurred when the $BaCl_2$ was added to the beaker. **2**

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(b) Calculate the percentage of sulfate in the lawn-food. **2**

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(c) The value quoted on the label for the % of sulfate was 25%. Based on the student's method, identify two reasons why he did not obtain this result. **2**

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Section II

12 marks
Attempt Question 28
Allow about 20 minutes for this section

Answer question 28 in a writing booklet. Extra writing booklets are available.
Show all relevant working in questions involving calculations

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Question 28 – Industrial Chemistry (12 marks) **Marks**

(a) Write an appropriate equation and describe what you observed for a reaction carried out in the laboratory to show sulfuric acid acting as:

(i) a dehydrating agent **2**

(ii) an oxidising agent **2**

(b) The industrial production of nitric acid involves several equilibrium steps.

(i) One step in the production of nitric acid involves the reaction of nitrogen monoxide with oxygen, according to the equation: **2**

$2NO\ (g) + O_2\ (g) \rightleftharpoons 2NO_2\ (g)$

This reaction is exothermic.
Describe TWO methods which could be used to increase the yield of nitrogen dioxide.

(ii) A 10 L reaction flask initially contained 2.5 mol NO and 1.2 mol O_2. After equilibrium was established, there was only 0.5 mol NO. **3**

Calculate the equilibrium constant for the reaction. Show all relevant working.

(c) Raw materials used in the production of sulfuric acid include sulfur and ores of sulfur.

(i) Describe the PHYSICAL processes used in the Frasch process and relate these physical processes to physical properties of sulfur. **2**

(ii) Outline ONE possible environmental issue associated with the extraction of sulfur by the Frasch process. **1**

End of Paper

Student Number

CHEMISTRY – MULTIPLE-CHOICE ANSWER SHEET

ATTEMPT ALL QUESTIONS

Question	**1**	A ○	B ○	C ○	D ○
	2	A ○	B ○	C ○	D ○
	3	A ○	B ○	C ○	D ○
	4	A ○	B ○	C ○	D ○
	5	A ○	B ○	C ○	D ○
	6	A ○	B ○	C ○	D ○
	7	A ○	B ○	C ○	D ○
	8	A ○	B ○	C ○	D ○
	9	A ○	B ○	C ○	D ○
	10	A ○	B ○	C ○	D ○
	11	A ○	B ○	C ○	D ○
	12	A ○	B ○	C ○	D ○
	13	A ○	B ○	C ○	D ○
	14	A ○	B ○	C ○	D ○
	15	A ○	B ○	C ○	D ○
	16	A ○	B ○	C ○	D ○
	17	A ○	B ○	C ○	D ○
	18	A ○	B ○	C ○	D ○
	19	A ○	B ○	C ○	D ○
	20	A ○	B ○	C ○	D ○

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DATA SHEET

Avogadro constant, N_A ..... 6.022×10^{23} mol^{-1}

Volume of 1 mole ideal gas: at 100 kPa and

at 0°C (273.15 K) ..... 22.71 L

at 25°C (298.15 K) ..... 24.79 L

Ionisation constant for water at 25°C (298.15 K), K_w ..... 1.0×10^{-14}

Specific heat capacity of water ..... 4.18×10^3 J kg^{-1} K^{-1}

Some useful formulae

$$pH = -\log_{10}[H^+] \qquad \Delta H = -m\,C\,\Delta T$$

Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

Aylward and Findlay, *SI Chemical Data* (5th Edition) is the principal source of data for this examination paper. Some data may have been modified for examination purposes.

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number — 79 — Symbol of element
Atomic Weight — Au 197.0 — Name of element
Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.41 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc [97.91] Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.8 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po [209.0] Polonium	85 At [210.0] Astatine	86 Rn [222.0] Radon
87 Fr [223] Francium	88 Ra [226] Radium	89–103 Actinoids	104 Rf [261] Rutherfordium	105 Db [262] Dubnium	106 Sg [266] Seaborgium	107 Bh [264] Bohrium	108 Hs [277] Hassium	109 Mt [268] Meitnerium	110 Ds [271] Darmstadtium	111 Rg [272] Roentgenium							

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm [145] Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.0 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac [227] Ion	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np [237] Neptunium	94 Pu [244] Plutonium	95 Am [243] Americium	96 Cm [247] Curium	97 Bk [247] Berkelium	98 Cf [251] Californium	99 Es [252] Einsteinium	100 Fm [257] Fermium	101 Md [258] Mendelevium	102 No [259] Nobelium	103 Lr [262] Lawrencium

For elements that have no stable or long-lived nuclides, the mass number of the nuclide with the longest confirmed half-life is listed between square brackets.

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (October 2005 version) is the principal source of data. Some data may have been modified.