



2022 AUSTRALIAN SCIENCE OLYMPIAD EXAM CHEMISTRY

TO BE COMPLETED BY THE STUDENT. USE CAPITAL LETTERS.

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Student Name:
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□ Male □ Female □ Unspecified Year 10 □ Year 11 □ Other:
Name of School: State:
Examiners Use Only:





2022 AUSTRALIAN SCIENCE OLYMPIAD EXAM CHEMISTRY

Time Allowed

Reading Time: 10 minutes
Examination Time: 120 minutes

INSTRUCTIONS

- Attempt all questions in ALL sections of this paper.
- Permitted materials: non-programmable, non-graphical calculator, pens, pencils, erasers and a ruler.
- Marks will not be deducted for incorrect answers.

MARKS

SECTION A 15 multiple choice questions 30 marks
 SECTION B 3 short answer questions 30 marks each

Total marks for the paper 120 marks

Integrity of Competition

If there is evidence of collusion or other academic dishonesty, students will be disqualified. Markers' decisions are final.

DATA

Avogadro constant (N) = $6.022 \times 10^{23} \text{ mol}^{-1}$	Velocity of light (c) = $2.998 \times 10^8 \text{ m s}^{-1}$
1 faraday = 96 485 coulombs	Density of water at 25 °C = 0.9971 g cm^{-3}
$1 \text{ A} = 1 \text{ C s}^{-1}$	Acceleration due to gravity = 9.81 m s^{-2}
Universal gas constant (R)	$1 \text{ newton (N)} = 1 \text{ kg m s}^{-2}$
$8.314 \text{ J K}^{-1} \text{ mol}^{-1}$	
$8.206 \times 10^{-2} \text{ L atm K}^{-1} \text{ mol}^{-1}$	
Planck's constant (h) = $6.626 \times 10^{-34} \text{J s}$	$1 \text{ pascal (Pa)} = 1 \text{ N m}^{-2}$
Molar volume of ideal gas	$pH = -\log_{10}[H^+]$
• at 0 °C and 100 kPa = 22.71 L	$pH + pOH = 14.00 \text{ at } 25^{\circ}C$
• at 25 °C and 100 kPa = 24.79 L	$K_{a} = \{[H^{+}][A^{-}]\} / [HA]$
• at 0 °C and 101.3 kPa = 22.41 L	$pH = pK_a + \log_{10}\{[A^-] / [HA]\}$
• at 25 °C and 101.3 kPa = 24.47 L	PV = nRT
	E = hv
Surface area of sphere $A = 4\pi r^2$	$c = v\lambda$

Periodic Table of Elements

1																	18
1 H 1.008	2		S	omic numi ymbo omic weig	ol							13	14	15	16	17	2 He 4.003
3	_4											5	6	7	8	9	10
Li 6.94	9.01											B 10.81	C 12.01	N 14.01	O 16.00	F 19.00	Ne 20.18
11	12											13	14	15	16	17	18
Na 22,99	Mg 24.31	3	4	5	6	7	8	9	10	11	12	AI 26.98	Si 28.09	P 30.97	S 32.07	CI 35.45	Ar 39.95
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
39.10	40.08	44.96	47.87	50.94	52.00	54.94	55.85	58.93	58.69	63.55	65.38	69.72	72.63	74.92	78.97	79.90	83.80
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb 85.47	Sr 87.62	Y 88.91	Z r 91.22	Nb 92.91	Mo 95.95	Tc ·	Ru 101.1	Rh 102.9	Pd 106.4	Ag	Cd 112.4	114.8	Sn 118.7	Sb 121.8	Te 127.6	126.9	Xe 131.3
55	56		72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs	Ba	57-71	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	TI	Pb	Bi	Po	At	Rn
132.9	137.3		178.5	180.9	183.8	186.2	190.2	192.2	195.1	197.0	200.6	204.4	207.2	209.0	-	-	-
87	88		104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
Fr	Ra	89-103	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	FI	Мс	Lv	Ts	Og

Γ	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
	138.9	140.1	140.9	144.2	-	150.4	152.0	157.3	158.9	162.5	164.9	167.3	168.9	173.0	175.0
Γ	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
	-	232.0	231.0	238.0		-	-	-	-	-	-	-	-	-	-

SECTION A: MULTIPLE CHOICE USE THE ANSWER SHEET PROVIDED

1.	dioxid	m sulfite (Na ₂ SO ₃) reacts with hydrochloric acid to produce sodium chloride, sulfur e and water. What volume (in mL) of 10.1 mol L ⁻¹ hydrochloric acid is required for ete reaction with 32.6 g of sodium sulfite?
	A.	12.8 mL
	B.	17.1 mL
	C.	25.6 mL
	D.	51.2 mL
	E.	102.4 mL
2.	Which	of the following pairs lists elements in order of increasing electronegativity?
	A.	Na, F, O, N
	B.	Na, O, F, N
	C.	Na, N, O, F
	D.	N, O, F, Na
	E.	Na, O, N, F
3.	Which state?	of the following contains molecules with linear molecular geometry in the solid
	A.	CO_2

B. KCl

C. MgO

D. GeO₂

E.

 $MgCl_2$

4.		stance conducts electricity well when liquid but not when solid. Which of the ing could this substance be? Select all that apply.
	A.	copper
	B.	sodium nitrate
	C.	argon
	D.	carbon tetrachloride
	E.	boron nitride
5.		ate the concentration of chloride ions in the resulting solution when 50.0 mL of $1.13 \text{ mol } \text{L}^{-1}$ silver nitrate n.
	A.	$0.49~\mathrm{mol}~\mathrm{L}^{-1}$
	B.	$0.67~\mathrm{mol}~\mathrm{L}^{-1}$
	C.	$0.85~\mathrm{mol}~\mathrm{L}^{-1}$
	D.	$1.34~\mathrm{mol}~\mathrm{L}^{-1}$
	E.	$1.55~\mathrm{mol}~\mathrm{L}^{-1}$
6.	What i	s the percentage by mass of fluorine in NF ₃ ?
	A.	31.13%
	B.	57.56%
	C.	73.06%
	D.	80.27%
	E.	87.15%

7. One step in the manufacture of aluminium is the production of aluminium hydroxide by the following process:

$$2 \text{ NaAlO}_2(aq) + 3 \text{ H}_2O(1) + \text{CO}_2(g) \rightarrow 2 \text{ Al}(OH)_3(s) + \text{Na}_2CO_3(aq)$$

What mass of aluminium hydroxide can be produced from a mixture of 40 g NaAlO₂, 15 g H₂O(l) and 10 g CO₂(g)?

- A. 17.7 g
- B. 21.6 g
- C. 35.4 g
- D. 38.1 g
- E. 43.3 g
- 8. How many hydrogen atoms are there in 0.2 mol of ammonium sulfate?
 - A. 6.0×10^{22}
 - B. 1.2×10^{23}
 - C. 2.4×10^{23}
 - D. 4.8×10^{23}
 - E. 9.6×10^{23}
- 9. Which of the following molecules has the highest boiling point?
 - A. CF₄
 - B. CCl₄
 - C. CBr₄
 - D. CI₄
 - E. CH₄

	E.	Sb
11.		t A has 3 valence electrons and element B has 6 valence electrons. Elements A and a the same period of the Periodic Table.
	What is	the likely formula of the compound that elements A and B form together?
	A.	AB
	B.	A_2B_3
	C.	AB_2
	D.	A_2B
	Е.	A_3B_3

10. Which of the following has the largest atomic radius?

Rb

Xe

K

D. Kr

A.

B.

C.

12.	Which	of the following substances has the highest boiling point?
	A.	bromine
	В.	magnesium bromide
	C.	phosphorus tribromide
	D.	hydrogen bromide
	E.	hydrogen
13.		um forms a number of oxides, one of which contains 78.08% rubidium by mass. What mpirical formula of this oxide?
	A.	Rb ₆ O
	B.	RbO
	C.	RbO_2
	D.	Rb ₂ O
	Е.	Rb_2O_3
14.	Select a	all molecules that have the same molecular shape.
	A.	CO_2
	B.	BF_3
	C.	Cl_2O
	D.	$\mathrm{H}_2\mathrm{S}$
	E.	CH ₄

15. 500 mL of a $0.10 \text{ mol } L^{-1}$ sodium chloride solution is prepared. To this sodium chloride solution, 500 mL of $0.10 \text{ mol } L^{-1}$ lithium chloride solution is added.

Which of the following describes the changes in concentration of sodium and chloride ions upon addition of the lithium chloride solution?

	$[Na^+]$
A.	Decreases
B.	Stays the same

[Cl⁻]

Increases

A. Decreases

C.

- B. Stays the same
- C. Increases

Question 16

carbonate ions (CO₃²⁻) together with other basic ions such as hydroxide (OH⁻) or oxide (O²⁻) and various metal cations. Carbonate content can be determined by measuring the mass of carbon dioxide given off when the mineral is treated with excess nitric acid. (a) Calculate the molar mass of the mineral with formula Pb₁₀O₃(CO₃)₆(OH)₂ (b) Balance the chemical equation for the reaction of this mineral with excess nitric acid. $Pb_{10}O_{3}(CO_{3})_{6}(OH)_{2} + HNO_{3} \rightarrow Pb(NO_{3})_{2} + CO_{2} + H_{2}O$ (c) Calculate the mass of carbon dioxide released when 10.00 g of this mineral reacts with excess nitric acid.

Basic carbonate minerals are found widely in nature and, as their name suggests, contain

(d) Calculate the chemical amount (in mol) of nitric acid required to react with 10.00 g of this mineral.
Basic carbonate minerals undergo thermal decomposition, forming metal oxides and releasing carbon dioxide and water, whose total mass can be determined by weighing.
(e) Balance the chemical equation for thermal decomposition of this mineral.
$Pb_{10}O_3(CO_3)_6(OH)_2 \rightarrow PbO + CO_2 + H_2O$
(f) Calculate the total mass lost when 10.00 g of this mineral is thermally decomposed.

only Pb²⁺, CO₃²⁻, OH⁻ and O²⁻ ions. When a 5.000 g sample of this mineral is treated with 25.00 mL of 2.000 mol L⁻¹ nitric acid (HNO₃), 0.5214 g of carbon dioxide is released, and 0.01051 mol of the acid remains. When subjected to thermal decomposition, 5.000 g of this mineral loses 0.5926 g. (g) Calculate the chemical amount (in mol or mmol) of nitric acid that reacts with the 5.000 g sample of this mineral. (h) Calculate the chemical amounts (in mol or mmol) of carbon dioxide and water released in the thermal decomposition. (i) Calculate the chemical amounts (in mol or mmol) of Pb²⁺, CO₃²⁻, OH⁻ present in the 5.000 g sample of this mineral. (j) Calculate the empirical formula of this mineral.

A sample of a different mineral is analysed by the same methods. This mineral also contains

Reaction A CO_3^{2-} ions present react to form HCO_3^- ions only; HCO_3^- ions present do not react further. $CO_3^{2-} + H^+ \rightarrow HCO_3^-$
Reaction B Both CO_3^{2-} ions and HCO_3^{-} ions present react completely to form CO_2 and H_2O . $CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$ $HCO_3^{-+} + H^+ \rightarrow CO_2 + H_2O$
A 6.000 g sample of a mineral containing only Na ⁺ , HCO ₃ ⁻ and CO ₃ ²⁻ ions is dissolved in water to form 100 mL of "dissolved mineral solution".
20.00 mL of "dissolved mineral solution" requires 10.32 mL of 0.5012 mol L^{-1} HCl in Reaction A , and 36.12 mL of 0.5012 mol L^{-1} HCl in Reaction B .
(k) Calculate the chemical amount of HCl consumed in reaction A. (in mol or mmol)
(l) Calculate the chemical amount of CO ₃ ²⁻ ions present in 20.00 mL of the "dissolved mineral solution".

A related series of water soluble minerals contain only Na⁺, HCO₃⁻ and CO₃²⁻ ions. Such minerals can be analysed by reaction with hydrochloric acid under two different reaction

conditions, which we will refer to as A and B.

(m)	Calculate the chemical amount of HCO ₃ ⁻ ions present in 20.00 mL of the "dissolved mineral solution".
(n)	Calculate the empirical formula of this mineral.

Question 17

¹H Nuclear Magnetic Resonance (NMR) is an extremely useful analytical technique as it can convey detailed information about the structure of molecules.

The number of signals in the ¹H NMR spectrum of a given molecule corresponds to the number of unique hydrogen atom environments in that molecule.

For example, chloromethane (CH₃Cl) has three hydrogen atoms in the same environment (i.e. attached to the same atom), so there is only one signal in its ¹H NMR spectrum.

By contrast, methanol (CH₃OH) has two different hydrogen atom environments, labelled H_a and H_b in the diagram below.

• The H_a atoms are bonded to the carbon atom, whereas H_b is bonded to the oxygen atom.

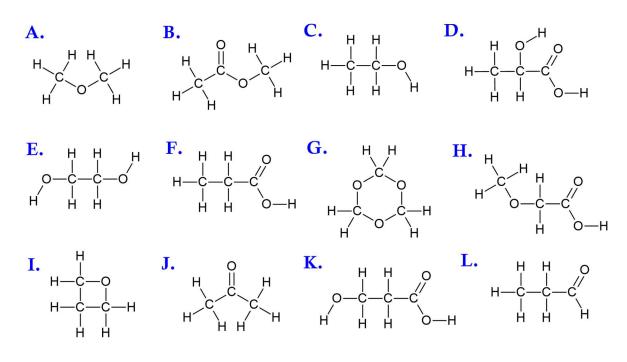
2-chloropropane also has two different hydrogen atom environments, labelled H_a and H_b in the diagram below.

- the 6 H_a atoms are present in two equivalent CH₃ groups on either end of the molecule.
- The single H_b atom is bonded to the central carbon atom.

1-chloropropane has three different hydrogen atom environments, labelled Ha, Hb and Hc.

(a)	How many signals would you expect in the ¹ H NMR spectrum of the following molecule?
	H H
(b)	How many signals would you expect in the ¹ H NMR spectrum of the following molecule?
	H H H H—C—C—H H H H
(c)	How many signals would you expect in the ¹ H NMR spectrum of the following molecule?
	H O H H O H H—C—C—H H H H

Use the following structures to answer the questions on this page.



(d) Using the identifying letters, which of the above molecules would you expect to have **one** signal in their ¹H NMR spectrum?

(e) Using the identifying letters, which of the above molecules would you expect to have **two** signals in their ¹H NMR spectrum?



(f) Using the identifying letters, which of the above molecules would you expect to have **four** signals in their ¹H NMR spectrum?



If a molecule contains two or more different hydrogen atom environments, ¹H NMR can also provide information about the relative the number of hydrogen atoms in each environment.

As we have seen before, methanol (CH₃OH) has two different hydrogen atom environments, labelled H_a and H_b in the diagram below.

There are 3 H_a atoms for every H_b atom. We can summarise this in table form:

Hydrogen atom	Relative number	
environment	of hydrogen atoms	
Ha	3	
H_b	1	

Similarly, 2-chloropropane has two different hydrogen atom environments, labelled H_a and H_b in the diagram below. There are 6 H_a atoms for every H_b atom.

Hydrogen atom	Relative number
environment	of hydrogen atoms
Ha	6
H _b	1

Normally the integral of the signal arising from the fewest protons is assigned an integral of 1, and all other integrals are expressed relative to that. This can give rise to non-integer integrals.

For example, methanamine has two different hydrogen atom environments: labelled H_a and H_b in the diagram below. The ratio hydrogen atoms is therefore 3:2, or more simply 1.5:1.

Hydrogen atom	Relative number
environment	of hydrogen atoms
Ha	1.5
H _b	1

Use the following structures to answer the questions on this page.

A.

H H H H
H
C
C
C
C
C
C
C
O

C. H O H H C C H H H H H H

F.

E.

H H H H
C C C C C O H
H H H H H

H H H H

(g) Using the identifying letters, which of the above molecules would you expect to give the following ¹H NMR data? Select all that apply.

Hydrogen atom environment	Relative number of hydrogen atoms
I	9
II	1

(h) Using the identifying letters, which of the above molecules would you expect to give the following ¹H NMR data? Select all that apply.

Hydrogen atom	Relative number
environment	of hydrogen atoms
I	6
II	2
III	1
IV	1

(i)	Using the identifying letters, which of the above molecules have at least one signal in their
	¹ H NMR spectrum with a relative number of hydrogen atoms of 1.5 ? Select all that apply.

Use the structures below to answer questions (j) to (m).

B. H O H H H H O C C C C H H H H H H H

D. H C C H H H H

G. H H H H H H H H H H H

H. O H H H H O C C C C C H H H H H

(j) Using the identifying letters, which of the above molecules have one signal in their ¹H NMR spectrum with a relative number of hydrogen atoms of **6**? Select all that apply.

(k) Using the identifying letters, which of the above molecules would you expect to give the following ¹H NMR data? Select all that apply.

Hydrogen atom environment	Relative number of hydrogen atoms
Ι	2
II	1
III	1

(1)	Using the identifying letters, which of the above molecules would you expect to give the
	following ¹ H NMR data? Select all that apply.

Hydrogen atom	Relative number	
environment	of hydrogen atoms	
Ι	3	
II	3	
III	1	
IV	1	

(m) Using the identifying letters, which of the above molecules would you expect to give the following ¹H NMR data? Select all that apply.

Hydrogen atom	Relative number
environment	of hydrogen atoms
I	3
II	3
III	2

Another useful aspect of ¹H NMR data is called chemical shift, a number usually between 0 and 12. Hydrogen atoms in specific chemical environments have characteristic chemical shifts, for example:

Hydrogen atom	Typical chemical shift range
environment	
$C-CH_x$	0.9 - 1.8
$O=C-CH_x$	2.0 - 2.7
$O-CH_x$	3.0 - 5.0
-СООН	10.5 - 12.0

(where x is 0, 1, 2 or 3)

For example:

Hydrogen atom	Chemical shift
environment	
Ha	2.1
H _b	11.4

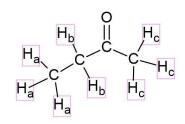
- The H_a atoms in the molecule above are adjacent to a C=O, so their chemical shift is between 2.0 2.7.
- The H_b atom is part of a -COOH group, so its chemical shift is between 10.5 12.0.

Similarly:

Hydrogen atom	Chemical shift
environment	
tt	1 4
Ha	1.4
H_b	3.5
H _c	3.3

- The H_a atoms in the molecule above are part of a C-CH₃ group, so their chemical shift is between 0.9 1.8.
- The H_b and H_c atoms are part of O–CH₂ and O–CH₃ groups respectively, so their chemical shifts are between 3.0-5.0.

(n) Predict the chemical shift of each different hydrogen atom in the following molecule.



Hydrogen atom	Chemical shift
environment	
Ha	
H _b	
H_{c}	

Use the structures below to answer questions (o) to (r).

(o) Using the identifying letters, which of the above molecules would you expect to give the following ¹H NMR data?

Hydrogen atom environment	Relative number of hydrogen atoms	Chemical shift
I	9	1.2
II	1	11.5

(p)	Using the identifying letters, which of the above molecules would you expect to give the
	following ¹ H NMR data?

Hydrogen atom environment	Relative number of hydrogen atoms	Chemical shift
I	6	1.2
II	1	2.6
III	3	3.7

(q) Using the identifying letters, which of the above molecules would you expect to give the following ¹H NMR data? Select all that apply.

Hydrogen atom environment	Relative number	Chemical shift
environment	of hydrogen atoms	
I	3	1.0
II	2	1.7
III	3	2.5
IV	2	4.0

(r) Using the identifying letters, which of the above molecules would you expect to give the following ¹H NMR data? Select all that apply.

Hydrogen atom	Relative number	Chemical shift
environment	of hydrogen atoms	
I	3	2.2
II	2	2.7
III	3	3.3
IV	2	3.6

Question 18

Let us consider the simplest types of reaction, those that happen in one step. We call these reactions elementary. For elementary reactions, the reaction rate (denoted by v) is dependent on the concentrations of each of the reactants.

For example, the elementary reaction $aA + bB \rightarrow cC$ has the rate law $v = k[A]^a[B]^b$, where k is a constant called the rate constant.

Consider the reaction between carbon monoxide and nitrogen trioxide:

$$CO(g) + NO_3(g) \rightarrow CO_2(g) + NO_2(g)$$

- (a) What is the rate law for this reaction?
 - (i) $v = k[CO_2][NO_2]$
- (ii) $v = k[NO_2]$
- (iii) $v = k[NO_3]$
- (iv) $v = k[CO_2]$
- (v) $v = k[CO][NO_3]$
- (vi) v = k[CO]

The exponents of the concentration terms in the rate law are known as the partial orders of the reaction. In the rate law $v = k[A]^a[B]^b$, reactant A has an order of a and reactant B has an order of b.

The overall reaction order is the sum of each reactant's order. In the above example, the overall reaction order is a + b.

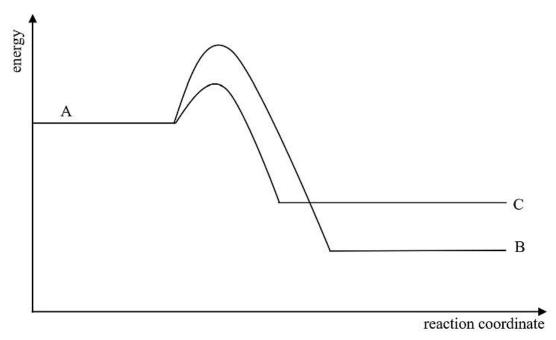
- (b) For the elementary reaction $CO(g) + NO_3(g) \rightarrow CO_2(g) + NO_2(g)$, identify the following:
 - (i) Partial reaction order of CO.
- (ii) Partial reaction order of NO₃.
- (iii) Overall reaction order.
- (c) For the elementary reaction $2 \text{ NO}(g) + O_2(g) \rightarrow 2 \text{ NO}_2(g)$, identify the following:
 - (i) Partial reaction order of NO.
- (ii) Partial reaction order of O₂.
- (iii) Overall reaction order.

(a)	For the elementary reaction $CO(g) + NO_3(g) \rightarrow CO_2(g) + NO_2(g)$: calculate the rate
	constant, k , if the reaction rate is $0.00491 \text{ mol } L^{-1} \text{ s}^{-1}$ when the [CO] is
	$0.137 \text{ mol } L^{-1}$ and [NO ₃] is $0.229 \text{ mol } L^{-1}$. Express your answer in L mol ⁻¹ s ⁻¹ .

- (e) Which of the following can increase the rate of a chemical reaction?
 - (i) Increasing the surface area of a solid reactant.
- (ii) Decreasing the temperature.
- (iii) Using a catalyst.
- (iv) For a gaseous reaction, decreasing the volume of a closed reaction vessel.
- (v) For an aqueous reaction, increasing the concentration of products.

The activation energy for a chemical reaction, E_A , represents the minimum energy that must be provided to the reactants for a chemical reaction to occur. Collision theory states that for a successful reaction to occur, reactant molecules must collide in the correct orientation and with energy that exceeds the activation energy.

The following energy profile diagram shows two possible products, B and C, that can be produced from reactant A.



(f) What is the major product when the reaction is allowed to run for 30 seconds at a low temperature?

(g) What is the major product when the reaction is allowed to run for 48 hours at a high temperature?

Collision theory states that for a successful reaction to occur, reactant molecules must collide in the correct orientation and with energy that exceeds the activation energy. The rate of reaction is proportional to the frequency of successful collisions. This can be represented by the following formula. The rate constant, k, is proportional to the reaction rate.

$$k = Ae^{-\frac{E_A}{RT}}$$

 E_A = activation energy (J), R = Universal Gas Constant, T = temperature (K), k = rate constant.

A is the pre-exponential factor, and is given by the formula:

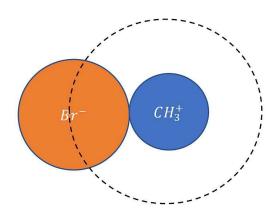
$$A = P \times N_A \times \sigma \times v$$

 N_A = Avogadro's constant; the other terms will be explained below.

Consider the following reaction: $CH_3^+ + Br^- \rightarrow CH_3Br$.

For this reaction to occur, a CH₃⁺ ion, with radius r_C, must come into contact with a Br⁻ ion, with radius r_B.

The σ term represents the area in which the two ions are close enough to collide, and can be calculated as the area of the dotted circle shown below.



- (h) Select the correct expression for σ for this reaction (the area of a circle is πr^2).
 - (i) $\pi(r_C-r_B)^2$
- (ii) $2\pi r_{\rm C}^2$
- $(iii) \qquad \pi r_C{}^2 \pi r_B{}^2$
- (iv) $\pi r_B^2 + \pi r_C^2$
- (v) $\pi (r_B + r_C)^2$

(i)	Select the molecular geometry of CH ₃ ⁺ .
(i)	tetrahedral
(ii)	linear
(iii)	trigonal planar
(iv)	trigonal pyramidal
(v)	T-shaped
	Using the fact that the radii of CH_3^+ and Br^- are 140 pm and 195 pm respectively, calculate σ for the reaction, in m^2 .

$v=\sqrt{rac{8k_BT}{\pi\mu}}$
In this formula, μ is the reduced mass, in kg, given by:
$\mu = \frac{m_1 m_2}{m_1 + m_2}$
where m_1 and m_2 are the masses of the colliding ions.
(k) Calculate the mass (in kg) of a Br ⁻ ion.
(l) Calculate the mass (in kg) of a CH ₃ ⁺ ion.
(m) Calculate the mass (in kg) of a CH ₃ ⁺ ion.
(n) Calculate v at 298 K for the above reaction, given that $k_B = 1.381 \times 10^{-23}$ m ² kg s ⁻² K ⁻¹ .

The v term represents the velocity (in ms^{-1}) of the particles as they collide, and is given by:

Recall the following formulae:

$$k = Ae^{-\frac{E_A}{RT}}$$

 E_A = activation energy (J), R = Universal Gas Constant, T = temperature (K), k = rate constant.

A is the pre-exponential factor, and is given by the formula:

$$A = P \times N_A \times \sigma \times v$$

(o)	Given that $\rho = 0.9$ and $E_A = -123$ kJ mol ⁻¹ , calculate the value of k for this reaction	at
	98 K.	

Reaction rates of enzymes can be described by the Michaelis-Menten equation:

$$v = \frac{V_{\text{max}}[S]}{K_{\text{m}} + [S]}$$

- v_ is the rate of reaction
- V_{max} is the maximum reaction rate
- [S] is the concentration of the enzyme's substrate (reactant)
- $K_{\rm m}$ is a constant

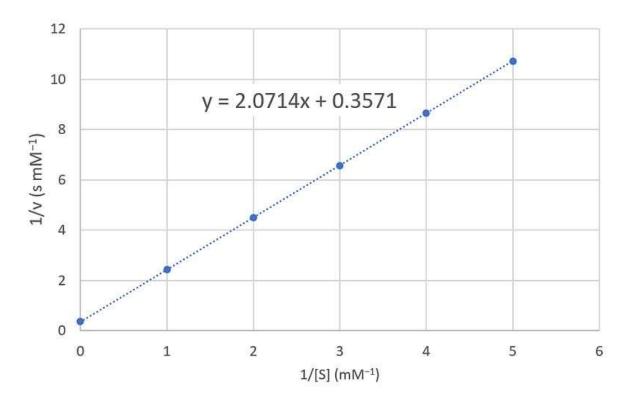
For the following changes, select the effect (if any) on the rate of reaction.

(p)	What effect does increasing the concentration of substrate from below $K_{\rm m}$ to above $K_{\rm m}$ have on the reaction rate?
(q)	What effect does using a different enzyme with a smaller K_m value have on the reaction rate?

The Michaelis-Menten equation can be re-written as follows:

$$\frac{1}{v} = \frac{K_{\rm m}}{V_{\rm max}} \cdot \frac{1}{[S]} + \frac{1}{V_{\rm max}}$$

A plot of 1/v_ against 1/[S] for a certain enzyme is shown below:



(r) What is the value of V_{max} for this enzyme?

(s) What is the value of $K_{\rm m}$ for this enzyme?

(t) At what [S] is the reaction rate equal to half V_{max} ?

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END OF EXAM