Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel Level 3 GCE

Time 1 hour 45 minutes

Paper reference **9CH0/02**

Chemistry

Advanced

PAPER 2: Advanced Organic and Physical Chemistry

You must have:
Scientific calculator, Data Booklet, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶

Q:1/1/1/1/1/1/

P 6 7 0 9 4 R A 0 1 2 4

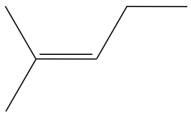
Pearson

Answer ALL questions.

Some questions must be answered with a cross in a box ☒.
If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 This is a question about polymers.

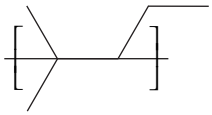
(a) An addition polymer is formed from 2-methylpent-2-ene.



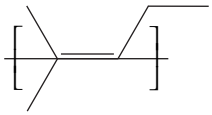
What is the repeat unit for poly(2-methylpent-2-ene)?

(1)

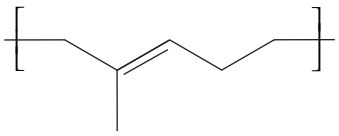
☒ **A**



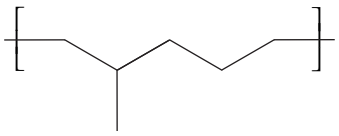
☒ **B**



☒ **C**



☒ **D**



(b) Which is **not** a use of waste poly(alkenes)?

(1)

☒ **A** feedstock for cracking

☒ **B** generation of biodegradable materials

☒ **C** incineration to release energy

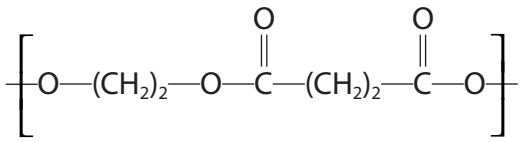
☒ **D** make new materials by recycling

(c) A condensation polymer can be made from ethane-1,2-diol and butanedioic acid.

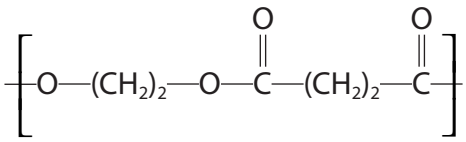
Which is the repeat unit for this polymer?

(1)

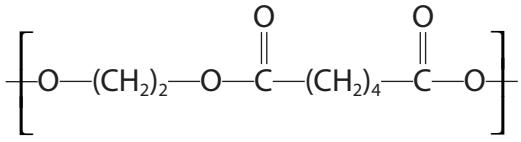
☒ **A**



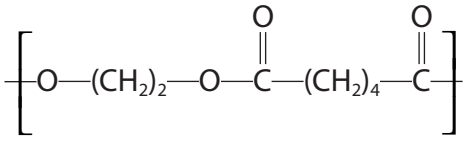
☒ **B**



☒ **C**



☒ **D**



(d) Which approach used by chemists would **not** contribute to a more sustainable use of materials over the life cycle of a polymer?

(1)

☒ **A** make more efficient use of energy

☒ **B** make more efficient use of resources

☒ **C** use catalysts for a faster reaction rate

☒ **D** use a higher temperature for a faster reaction rate

(Total for Question 1 = 4 marks)

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2 This is a question about hydrocarbons.

(a) State what is meant by the term **hydrocarbon**.

(1)

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.....

(b) Explain why 2,2-dimethylpropane has a much lower boiling temperature than its isomer pentane.
Detailed descriptions of the forces involved are not required.

(2)

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.....

(c) The **heterolytic** bond fission of a sigma (σ) bond in an alkane would produce

(1)

☒ **A** only carbocations

☒ **B** only free radicals

☒ **C** free radicals and ions

☒ **D** ions

(Total for Question 2 = 4 marks)

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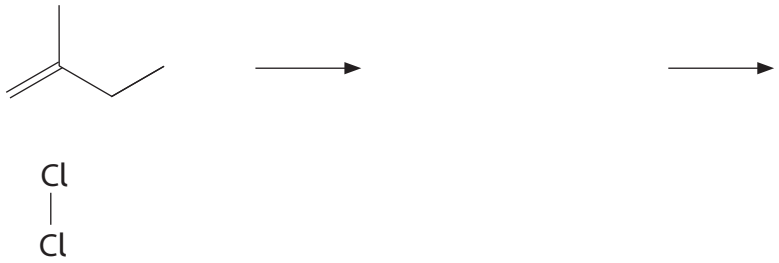
3 This is a question about dihalogenoalkanes.

(a) Dihalogenoalkanes are formed when alkenes react with halogens.

(i) Complete the mechanism for the production of a dihalogenoalkane from 2-methylbut-1-ene and chlorine.
Include curly arrows and any relevant lone pairs.

(3)



(ii) Give the name of the dihalogenoalkane produced.

(1)

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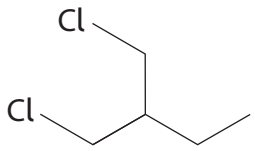
(b) What is the classification of the dihalogenoalkane shown?



(1)

- ☒ **A** primary
- ☒ **B** secondary
- ☒ **C** tertiary
- ☒ **D** primary and secondary

(Total for Question 3 = 5 marks)

4 This question is about nitrogen and some nitrogen compounds.

(a) A study of one brand of crisps found that each packet contained 0.420 g of nitrogen gas at a pressure of 120 kPa and a temperature of 20 °C.

(i) Calculate the volume of nitrogen gas, in **cm^3**, in one packet of crisps.

[$R = 8.31\ \text{J mol}^{-1}\ \text{K}^{-1}$]

(4)

(ii) Give a possible reason why nitrogen gas and not air is used in packets of crisps.

(1)

.....

.....

(b) Draw dot-and-cross diagrams for a molecule of nitrogen gas and for the nitride ion, N^{3-}, in sodium nitride, Na_3N.

Use dots (•) for nitrogen electrons and crosses (**X**) for electrons from sodium.

(2)

Nitrogen molecule

Nitride ion

(c) Ammonia accepts a proton to form an ammonium ion.

$$NH_3 + H^+ \rightarrow NH_4^+$$

Explain why the ammonia molecule and the ammonium ion have different shapes and different bond angles.

(4)

(d) Butylamine, $C_4H_9NH_2$, reacts with ethanoyl chloride.

$$2C_4H_9NH_2 + CH_3COCl \rightarrow C_4H_9NHCOCH_3 + C_4H_9NH_3^+Cl^-$$

Explain how this equation illustrates that butylamine acts as a nucleophile and as a base.

(4)

(Total for Question 4 = 15 marks)

5 Ice has a density of 0.92 g cm^{-3} and water has a density of 1.00 g cm^{-3}.

(a) About 200 cm^3 of water and 200 cm^3 of cooking oil were placed in a large beaker and two layers formed. The cooking oil formed the upper layer.

An ice cube made from water with a water-soluble blue food dye was added.

Initially the ice cube floated on top of the cooking oil but on melting the blue-coloured water sank into the bottom layer of water.

Give a possible value for the density of the cooking oil. Justify your answer.

(2)

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(b) Calculate how many **more** molecules there are in 5.00 cm^3 of water compared to 5.00 cm^3 of ice.

(3)

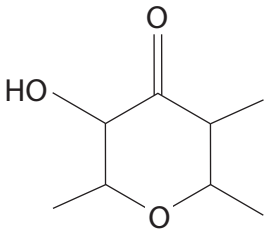
(Total for Question 5 = 5 marks)

6 Aldehydes and ketones are carbonyl compounds.

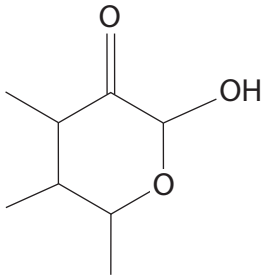
(a) Which of these compounds does **not** contain a ketone functional group?

(1)

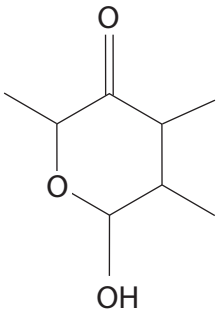
☒ **A**



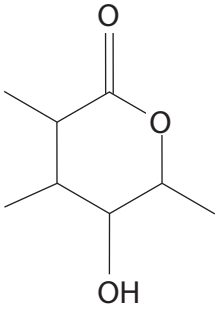
☒ **B**



☒ **C**



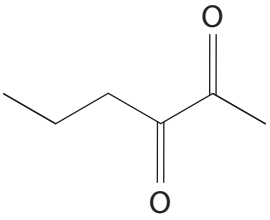
☒ **D**



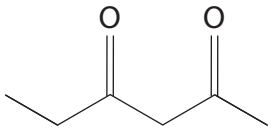
(b) Which of these compounds has both an aldehyde functional group **and** a ketone functional group?

(1)

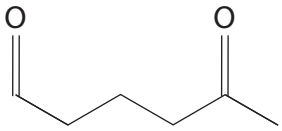
☒ **A**



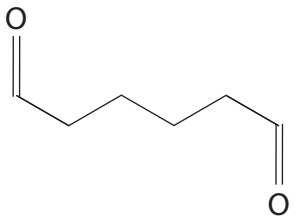
☒ **B**



☒ **C**

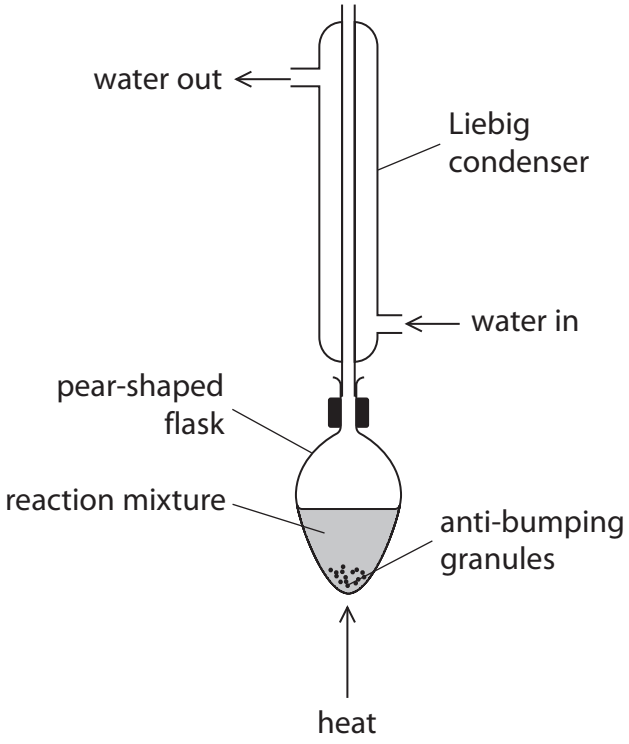


☒ **D**



(c) Propanal can be produced from the oxidation of propan-1-ol.

(i) A student assembled the apparatus shown for this oxidation.



Explain why the use of this apparatus would give a very low yield of propanal.

(2)

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(ii) The oxidising agent is acidified $Na_2Cr_2O_7$.

State the oxidation number of chromium in $Na_2Cr_2O_7$.

(1)

.....

(iii) Complete the ionic half-equation for the oxidation of propan-1-ol.

(1)

$$CH_3CH_2CH_2OH \rightarrow CH_3CH_2CHO + \text{.....}H^+ + \text{.....}e^-$$

(iv) State how the use of anti-bumping granules gives smoother boiling.

(1)

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(v) Another student used the correct apparatus for this oxidation.
1.50 g of propan-1-ol produced 0.609 g of propanal.

Calculate the percentage yield of propanal by mass.

(3)

(d) The table contains data on propanone and ethanoic acid.

Substance	Molar mass / g mol^{-1}	Boiling temperature / °C	Solubility in water
Propanone	58	56	completely miscible
Ethanoic acid	60	118	completely miscible

(i) Explain, by reference to the data and any intermolecular forces involved, the difference in the boiling temperatures.

(4)

(ii) Explain, with the aid of a diagram, why propanone is completely miscible with water.

(2)

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(Total for Question 6 = 16 marks)

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7 Organic compounds containing nitrogen include amides, amines, amino acids and nitriles.

(a) Propylamine, $CH_3CH_2CH_2NH_2$, may be formed from either a nitrile or a halogenoalkane.

(i) Give the reagent and essential condition for the formation of propylamine from a nitrile.
Include an equation for the reaction.

(2)

(ii) Give the reagent and essential conditions for the formation of propylamine from a halogenoalkane.
Include an equation for the reaction.

(3)

(b) A compound produced a peak due to an N—H stretching vibration in its infrared spectrum with a wavenumber of 3220 cm^{-1}.

This compound could be

(1)

- ☒ **A** an amide
- ☒ **B** an amine
- ☒ **C** either an amide or an amine
- ☒ **D** neither an amide nor an amine

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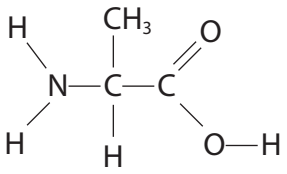
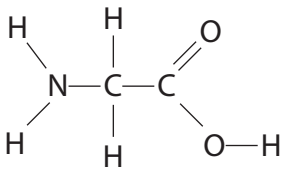
*(c) Alanine and glycine are amino acids.

Amino acid	Structure
alanine	
glycine	

Compare and contrast the structures, optical activity and reactions with acids and bases of alanine and glycine.

Include diagrams, structures and equations to illustrate your answer.

(6)

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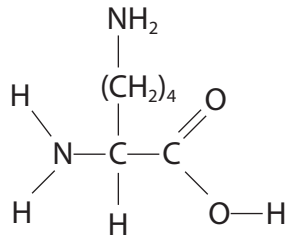
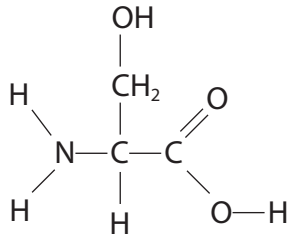
(d) Lysine and serine are two more amino acids.

Amino acid	Structure of amino acid
lysine	
serine	

Explain the difference in the volumes of 0.010 mol dm^{-3} hydrochloric acid required to completely react with separate 10.0 cm^3 samples of aqueous lysine and of aqueous serine, both of concentration 0.010 mol dm^{-3}.

(2)

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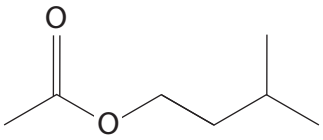
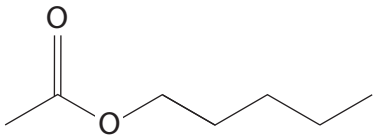
(Total for Question 7 = 14 marks)

8 Esters have many uses due to their characteristic aromas and often have common names. For example, isoamyl acetate is referred to as banana oil and amyl acetate has a scent similar to apples.



isoamyl acetate



amyl acetate

(a) What is the number of peaks in a ^{13}C NMR spectrum of isoamyl acetate and of amyl acetate?

(1)

		isoamyl acetate	amyl acetate
☒	**A**	5	6
☒	**B**	6	6
☒	**C**	6	7
☒	**D**	7	7

(b) State the molecular formula of amyl acetate.

(1)

.....

(c) Deduce the structural formula of the carboxylic acid that could be used to form both isoamyl acetate and amyl acetate.

(1)

(d) Deduce the **name** of the alcohol that forms isoamyl acetate.

(1)

.....

(e) Give the systematic name for amyl acetate.

(1)

.....

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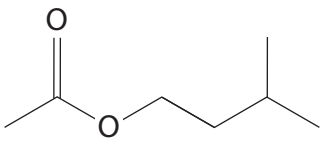
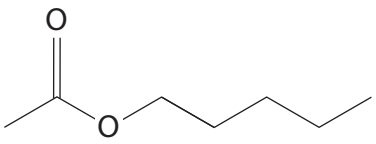
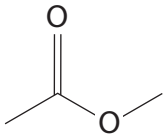
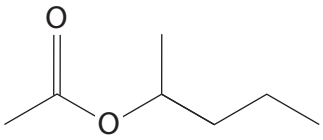
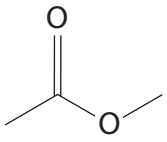
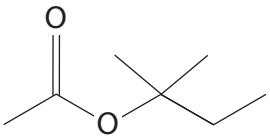
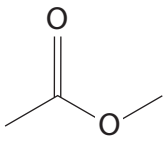
(f) The carboxylic acid used to make isoamyl acetate and amyl acetate can also be used to make six further ester isomers. The structures of two of these esters, **A** and **B**, are shown.

(i) Complete the **skeletal** formulae of **three** of the remaining esters. Names are **not** required.

(3)

 isoamyl acetate	 amyl acetate	
 ester **A**		
 ester **B**		

(ii) Write an equation to show the formation of ester **A** from an acyl chloride and an alcohol.

(2)

(g) Esters can be hydrolysed by heating under reflux with aqueous acid or alkali.

Compare and contrast these two methods of hydrolysis for amyl acetate.

(4)

(Total for Question 8 = 14 marks)

9 At high temperatures, ethanal decomposes to form methane and carbon monoxide.
The reaction is second order with respect to ethanal and second order overall.

$$CH_3CHO \rightarrow CH_4 + CO$$

(a) Write the rate equation for this reaction.

(1)

(b) Deduce the units of the rate constant given that the units of rate are mol dm^{-3} s^{-1}.

(1)

(c) The table shows the concentration of ethanal in a sample at different times.

Time / s	Concentration of ethanal / mol dm^{-3}
0	0.72
420	0.36
1260	0.18

Calculate average values for the rate of reaction between 0 and 420 seconds and between 420 and 1260 seconds.
Give your answers to an appropriate number of significant figures.

(2)

0 s – 420 s .....

420 s – 1260 s .....

(d) Explain why the data given and your answers in (c) show that the reaction is **neither** zero order **nor** first order.

(2)

(e) The rate constant for the reaction was determined at five temperatures. The results are given in the table.

Temperature (T) / K	1/ Temperature ($1/T$) / K^{-1}	Rate constant (k) / units in (b)	$\ln k$
700	1.43×10^{-3}	0.011	–4.51
730	1.37×10^{-3}	0.035	–3.35
760	1.32×10^{-3}	0.105	–2.25
790		0.343	
810	1.23×10^{-3}	0.787	–0.24

Determine the activation energy, E_a, in $kJ\,mol^{-1}$, by completing the data in the table and plotting a graph of $\ln k$ against $1/T$.

You should include the value of the gradient of the line and its units.

The Arrhenius equation can be expressed as $\ln k = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant}$

(7)

Total for Question 9 = 13 marks)

TOTAL FOR PAPER = 90 MARKS

The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
							1.0 H hydrogen 1										(18) 4.0 He helium 2
(1)	(2)		Key									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4		relative atomic mass atomic symbol name atomic (proton) number									10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

* Lanthanide series

* Actinide series