Uni Cambridge **CHEMISTRY** NSAA

Natural Science Admissions Assessment Cambridge

2016sp to 2022 (19 papers)

Mapped to CAIE A Level Chemistry

Contents

Information about the NSAA

From: https://www.undergraduate.study.cam.ac.uk/courses/natural-sciences#entry-requirements (accessed September 2020)

For 2021 entry, applicants for Natural Sciences are required to take a pre-interview written assessment on 5 November 2020, at an authorised centre local to them (for a lot of applicants, this will be their school/college). You need to be registered by 15 October 2020 to take the assessment, and your assessment centre must do this for you. Please note that open centres may set an earlier deadline for accepting entries, and it is your responsibility to check if this applies at your centre. See admission assessments for full details.

Assessment format

The format for the 2020 assessment will be as follows:

- **Section 1**: Multiple choice questions in mathematics plus one science (Biology, Chemistry or Physics) (60 minutes)
- **Section 2**: Extended multiple choice questions in Biology, Chemistry or Physics (60 minutes)

Please note that your performance in the pre-interview assessment will not be considered in isolation, but will be taken into account alongside the other elements of your application.

Specimen and past papers

A specimen paper has been produced to allow you to sample the written assessment format and practice under timed conditions. It is not expected that you will answer every question correctly; the written assessment is designed to be challenging. Even some strong candidates may not complete the paper in the time allowed; it is designed to distinguish across our field of high-calibre applicants.

Experience with similar assessments and from trials indicates that, on average, typical applicants to the most highly selective undergraduate courses (who are by definition academically very able) **will gain approximately half of the available marks**. The best applicants will score more highly, but only **relatively few are expected to gain more than 80 per cent** of the available marks.

Written assessments help admissions tutors to assess whether candidates have the skills, aptitudes and any required subject knowledge and understanding required to study the relevant course at Cambridge. They are only one of the elements used in the admissions process. Others include a candidate's academic record and forecast grades in school-leaving examinations; UCAS application form; examples of recent written work submitted to the College to which they are applying; and performance at interview, if invited to attend.

When using the specimen and past papers below, please note the following changes to the 2020 Natural Sciences admissions assessment:

From: https://www.undergraduate.study.cam.ac.uk/apply/how/natural-sciences-admission-test (accessed September 2023)

Changes to the assessment format

Please be aware that Section 2 Biology was updated in 2022. Section 2 Biology now tests knowledge of advanced topics, bringing it in line with Section 2 Physics and Chemistry. You should take this into consideration when looking at past papers.

In addition, the following changes were made to the Natural Sciences Admissions Assessment (NSAA) in 2020.

NSAA	From 2020	In previous years
Section 1	▪ 60 minutes ▪ 4 parts, of which candidates should answer 2 (mathematics and one of the sciences). Each part contains 20 multiple-choice questions.	▪ 80 minutes ▪ 5, parts, of which candidates should answer 3. Each part contains 18 multiple-choice questions.
Section 2	▪ 60 minutes ▪ 3 parts, of which candidates should answer 1. Each part contains 20 multiple-choice questions. ▪ Marking solely based on answers on multiple choice answer sheet ▪ **Calculators not permitted**	▪ 40 minutes ▪ 6 questions, of which candidates answer 2 ▪ Marking took account of working provided on question paper ▪ Calculators permitted

Additional information

There is a strong focus on mental arithmetic (both sections now do not allow a calculator. IB Chemistry Higher Level Topic 1 might help provide additional practice for these kinds of questions.

Some question numbers aren't assigned to actual questions, this is a problem that will be fixed in the next draft, the questions aren't missing, it's just an artefact of the process used to compile this.

There is a note about when marking would happen for the 2016 exam for Biology, at 11th November, the exam was on the 2nd November, which implies that the marking of them happens as one might expect, and before the interviews.

A note on how marks were assigned topics

Sometimes topic boundaries are blurred, for instance reactivity from periodicity and electrochemistry.

For section 1 most of the material mapped to AS except electrolysis which is instead found in A2 Topic 24.

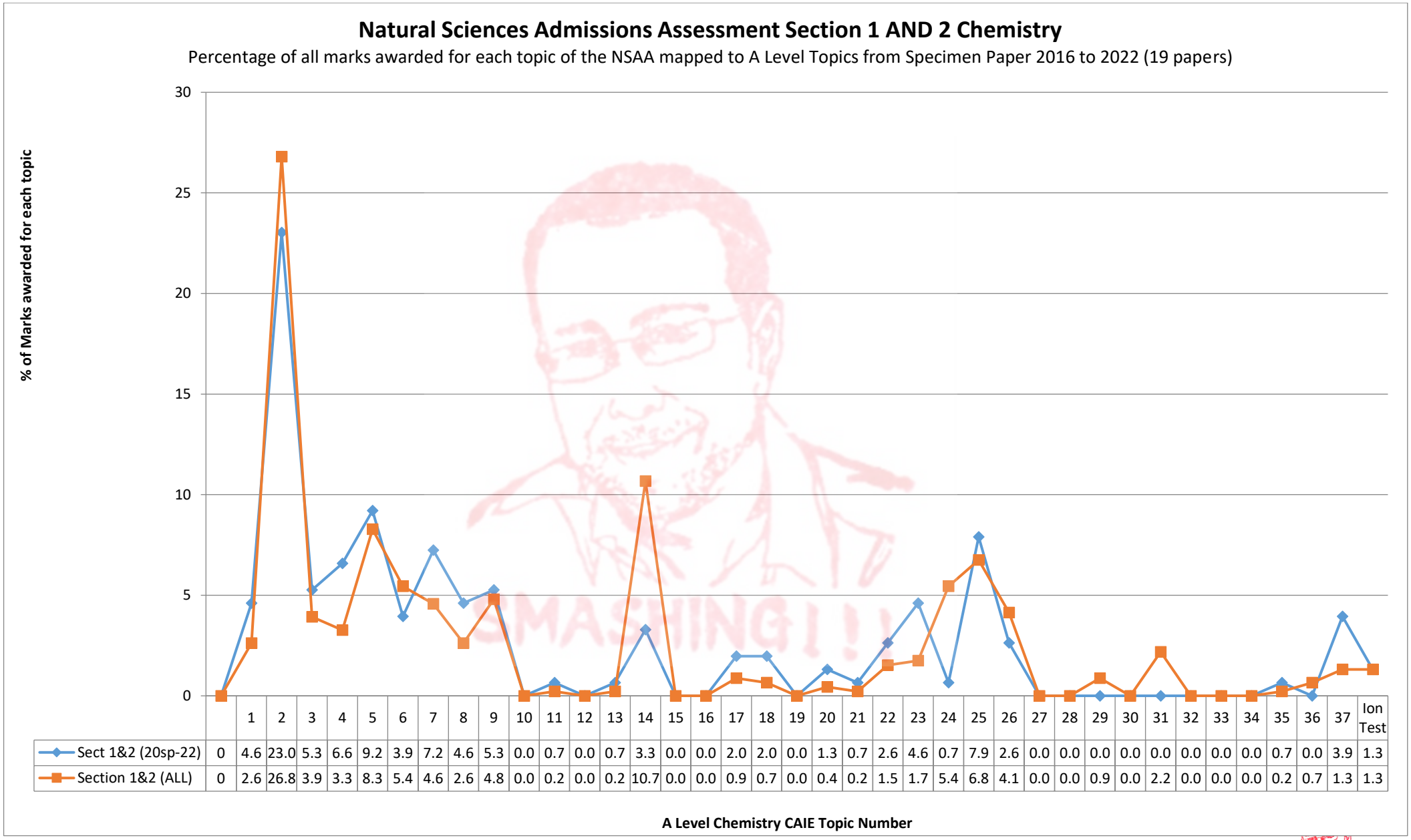
Also, a couple of questions, labelled with 2x, examined a range of topics in a sequential way that made it hard to satisfactorily slice the questions into disparate topics, though the marks were assigned correctly. This is for the older short answer section 2 before it became all multiple choice, so a lot less relevant moving ahead.

For more practice on the all important topic 2 (stoichiometry) you can look at IB Higher Level (IB Topic number 1) questions, which can be found here:

https://www.smashingscience.org/ib-chemistry-hl-sl

Remember, these questions need to be done without a calculator, and if there are about 3 steps to an IB HL question, there are 5 to 7 steps for a calculation question in the NSAA. So being quick o these kind of questions is key.

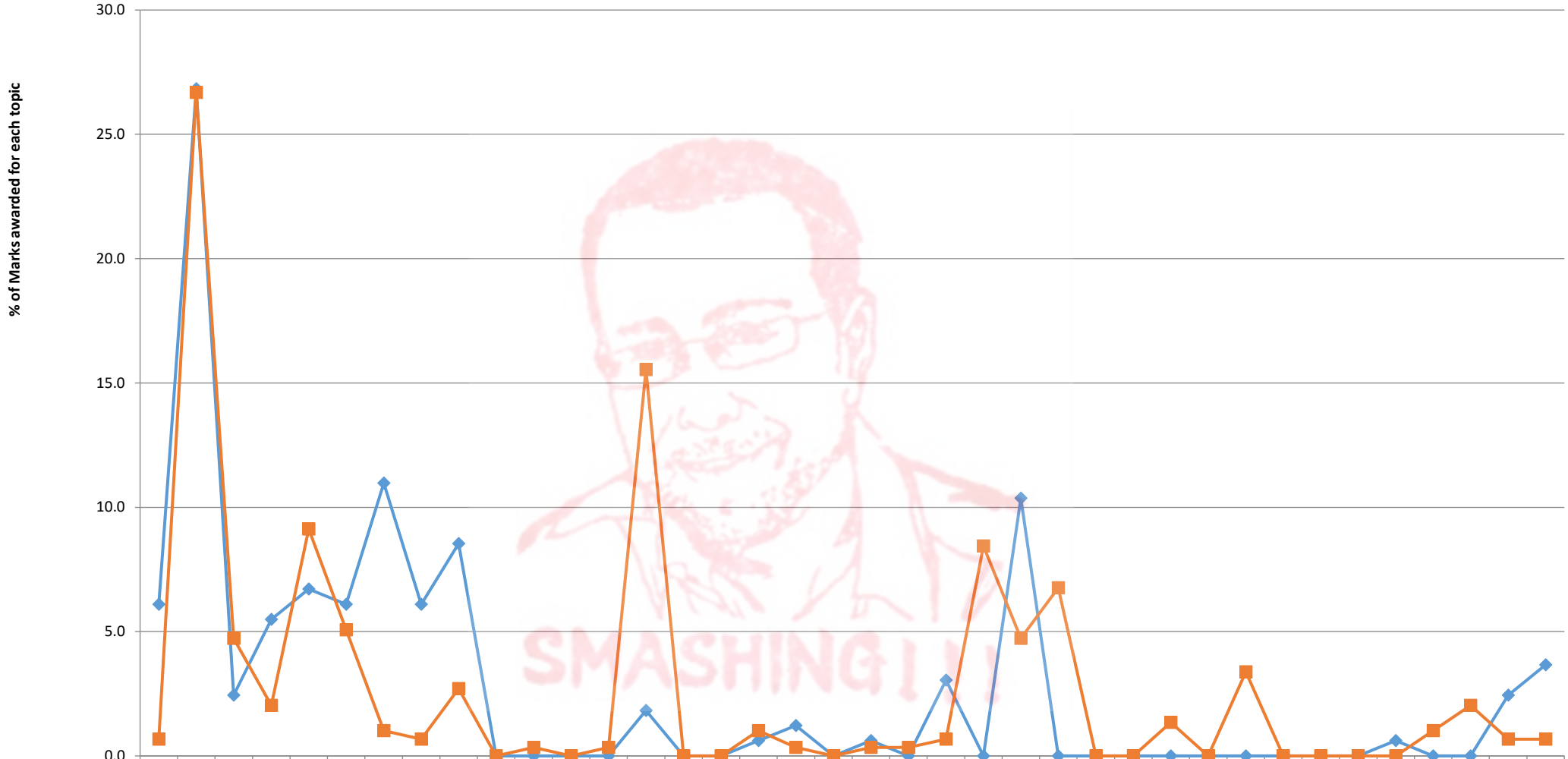
Comparing marks allocated to each topic



		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	Ion Test
Sect 1&2 (20sp-22)	0	4.6	23.0	5.3	6.6	9.2	3.9	7.2	4.6	5.3	0.0	0.7	0.0	0.7	3.3	0.0	0.0	2.0	2.0	0.0	1.3	0.7	2.6	4.6	0.7	7.9	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	3.9	1.3
Section 1&2 (ALL)	0	2.6	26.8	3.9	3.3	8.3	5.4	4.6	2.6	4.8	0.0	0.2	0.0	0.2	10.7	0.0	0.0	0.9	0.7	0.0	0.4	0.2	1.5	1.7	5.4	6.8	4.1	0.0	0.0	0.9	0.0	2.2	0.0	0.0	0.0	0.2	0.7	1.3	1.3

Natural Sciences Admissions Assessment Section 1 Chemistry Compared with Section 2

Percentage of all marks awarded for each topic of the NSAA mapped to A Level Topics from Specimen Paper 2016 to 2022 (19 papers)



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	Ion Test
Section 1	6.1	26.8	2.4	5.5	6.7	6.1	11.0	6.1	8.5	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.6	1.2	0.0	0.6	0.0	3.0	0.0	10.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	2.4	3.7
Section 2	0.7	26.7	4.7	2.0	9.1	5.1	1.0	0.7	2.7	0.0	0.3	0.0	0.3	15.5	0.0	0.0	1.0	0.3	0.0	0.3	0.3	0.7	8.4	4.7	6.8	0.0	0.0	1.4	0.0	3.4	0.0	0.0	0.0	0.0	1.0	2.0	0.7	0.7

Comments on the distribution of marks

As the comparison with the most recent versus all of the exams, the general trends seems to be stable in which topics are examined more often.

These topics are ordered by mark frequency for the most recent exams, which all use the 2023 new exam format. These map well with all of the exams, with the exception of topic 14 (organis) which is substantially less in more recent exams, and topic 24 (electrochemistry) which was less frequent, and is now even rarer.

	Sect 1&2 (20sp-22)	Section 1&2 (ALL)	Section 1	Section 2
2	23.0	26.8	26.8	26.7
5	9.2	8.3	6.7	9.1
25	7.9	6.8	0.0	6.8
7	7.2	4.6	11.0	1.0
4	6.6	3.3	5.5	2.0
3	5.3	3.9	2.4	4.7
9	5.3	4.8	8.5	2.7
1	4.6	2.6	6.1	0.7
8	4.6	2.6	6.1	0.7
23	4.6	1.7	0.0	8.4
6	3.9	5.4	6.1	5.1
37	3.9	1.3	2.4	0.7
14	3.3	10.7	1.8	15.5
22	2.6	1.5	3.0	0.7
26	2.6	4.1	0.0	0.0
17	2.0	0.9	0.6	1.0
18	2.0	0.7	1.2	0.3
20	1.3	0.4	0.6	0.3
Ion Tests	1.3	1.3	3.7	0.7
11	0.7	0.2	0.0	0.3
13	0.7	0.2	0.0	0.3
21	0.7	0.2	0.0	0.3
24	0.7	5.4	10.4	4.7
35	0.7	0.2	0.0	1.0
10	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	1.4
29	0.0	0.9	0.0	0.0
30	0.0	0.0	0.0	3.4
31	0.0	2.2	0.0	0.0
32	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0
34	0.0	0.0	0.6	0.0
36	0.0	0.7	0.0	2.0

What score do you need to be accepted?

The NSAA is just one part of the process, but looking at averages for it and accepted students, doing better in it will likely ensure you get an interview (no students with an unusually high score in it were denied an interview, but students with lower scores get accepted, and higher scores get rejected.

St John's College has published analysis for 2020 application year:

1) The range and mean NSAA Section 1 & 2 scores for those made offers by St John's for Physical or Biological Natural Sciences:

*** range for Section 1 = 9.0 - 27.0**
*** mean for Section 1 = 18.05**
*** range for Section 2 = 11.0 - 40.0**
*** mean for Section 2 = 28.27**

2) The range and mean NSAA Section 1 & 2 scores for Physical and Biological Natural Sciences applicants placed by St John's in the Winter Pool:

* range for Section 1 = 6.8 - 25.6
* mean for Section 1 = 14.86
* range for Section 2 = 6.0 - 38.0
* mean for Section 2 = 22.91

3) The range and mean NSAA Section 1 & 2 scores for Physical and Biological Natural Sciences applicants rejected by St John's:

* range for Section 1 = 3.1 - 25.8
* mean for Section 1 = 11.51
* range for Section 2 = 3.0 - 36.5
* mean for Section 2 = 19.79

4) The range and mean NSAA Section 1 & 2 scores for Physical and Biological Natural Sciences applicants **not invited** by St John's for interview:

* range for Section 1 = 3.1 - **22.3**
*** mean for Section 1 = 11.95**
* range for Section 2 = 3.0 - **37.0**
*** mean for Section 2 = 20.49**

5) The range and mean NSAA Section 1 & 2 scores for Physical and Biological Natural Sciences applicants invited by St John's for interview:

* range for Section 1 = **6.8** - 27.0
*** mean for Section 1 = 17.02**
* range for Section 2 = 6.0 - 40.0
*** mean for Section 2 = 26.32**

6) The range and mean interview scores of Physical and Biological Natural Sciences applicants who were made offers by St John's:

*** range = 7.0 - 9.3**
*** mean = 7.89**

7) The range and mean interview scores of Physical and Biological Natural Sciences applicants who were rejected by St John's:

* range = 4.3 - 8.5
* mean = 6.43

For clarity the 2020 application year ran from applications opening in September 2019 to confirmation in August 2020.

From: https://www.whatdotheyknow.com/request/natural_sciences_applications_20_21

The key take away is that higher test scores do track with acceptance, but they are obviously not the only or most important part to the selection process. Interestingly, there is a scoring process for the interview. One student got nearly a perfect sore (37) for section 2 but was not invited to interview, they could have had a problem with their GCSE or AS grades, or also possible, a problem with their personal statement (e.g. plagiarised) or their reference.

Another request under the Freedom of Information Act which I have processed, *a really rough draft* of some of this analysis is below, gives further clarity about offers made against various NSAA achievement profiles for the different subjects:

ApplyID	Offer Holder	Maths	Physics	Biology	Chemistry	Advanced Maths	Section 2 B1	Section 2 B2	Section 2 C1	Section 2 C2	Section 2 P1	Section 2 P2
Average ALL	Yes & No	11	9	9	8	7	6	12	11	11	9	9
Average Rejected		10	8	8	8	6	6	11	9	10	8	8
Average Accepted	**Yes & No**	**14**	**12**	**11**	**11**	**10**		**14**	**14**	**14**	**12**	**11**
Total applications	270	1045	975	235	483	399	8	106	413	474	429	634

From: https://www.whatdotheyknow.com/request/statistics_for_applicants_for_ph#incoming-1693531

More information about averages (this time for the Veterinary Science course) can be found here:

Course	Accepted	Apply Year	NSAA Section	Average Score
Veterinary Medicine (D100)	NSAA	2018	Advanced Maths	5.4
Veterinary Medicine (D100)	NSAA	2018	Biology	4.3
Veterinary Medicine (D100)	NSAA	2018	Chemistry	4.1
Veterinary Medicine (D100)	NSAA	2018	Maths	3.7
Veterinary Medicine (D100)	NSAA	2018	Physics	3.8
Veterinary Medicine (D100)	NSAA	2018	Section 2 B1	11.8
Veterinary Medicine (D100)	NSAA	2018	Section 2 B2	12.2
Veterinary Medicine (D100)	NSAA	2018	Section 2 C1	12.7
Veterinary Medicine (D100)	NSAA	2018	Section 2 C2	14.7
Veterinary Medicine (D100)	NSAA	2018	Section 2 P1	7.5
Veterinary Medicine (D100)	NSAA	2018	Section 2 P2	9.0
Veterinary Medicine (D100)	NSAA	2019	Biology	4.6
Veterinary Medicine (D100)	NSAA	2019	Chemistry	4.6
Veterinary Medicine (D100)	NSAA	2019	Maths	3.5
Veterinary Medicine (D100)	NSAA	2019	Physics	3.3
Veterinary Medicine (D100)	NSAA	2019	Section 2 B1	11.4
Veterinary Medicine (D100)	NSAA	2019	Section 2 B2	12.4
Veterinary Medicine (D100)	NSAA	2019	Section 2 C1	15.2
Veterinary Medicine (D100)	NSAA	2019	Section 2 C2	11.4
Veterinary Medicine (D100)	NSAA	2020	Biology	4.4
Veterinary Medicine (D100)	NSAA	2020	Chemistry	4.8
Veterinary Medicine (D100)	NSAA	2020	Maths	3.4
Veterinary Medicine (D100)	NSAA	2020	Physics	5.0
Veterinary Medicine (D100)	NSAA	2020	Section 2 B1	8.3
Veterinary Medicine (D100)	NSAA	2020	Section 2 B2	11.6
Veterinary Medicine (D100)	NSAA	2020	Section 2 C1	10.7
Veterinary Medicine (D100)	NSAA	2020	Section 2 C2	11.2
Veterinary Medicine (D100)	NSAA	2021	S1 Biology	5.0
Veterinary Medicine (D100)	NSAA	2021	S1 Chemistry	2.6
Veterinary Medicine (D100)	NSAA	2021	S1 Maths	3.7
Veterinary Medicine (D100)	NSAA	2021	S2 Biology	4.4
Veterinary Medicine (D100)	NSAA	2021	S2 Chemistry	3.6

A good explanation for this wide variability in scores is the emphasis this course places on other things, especially a strong personal statement and portfolio of experiences related to the subject.

From: https://www.whatdotheyknow.com/request/admission_statistics_for_undergr_23#incoming-1995334

UMS performance and the eventual HE destination of Cambridge applicants

From: https://www.cao.cam.ac.uk/ums-performance-and-eventual-he-destination-cambridge-applicants

UNIVERSITY OF CAMBRIDGE
Academic Division
Cambridge Admissions Office

PATTERNS OF APPLICATION

UMS performance and the eventual HE destination of Cambridge applicants

The emphasis placed on attainment at AS-level in the Cambridge admissions process makes it very probable that those applicants who are successful in obtaining an offer of a place at the University have a stronger academic record than those who are unsuccessful. While it is difficult to capture in statistics the full assessment made of an applicant's academic record, a proxy through which to operationalise relative attainment is through the use of UMS.

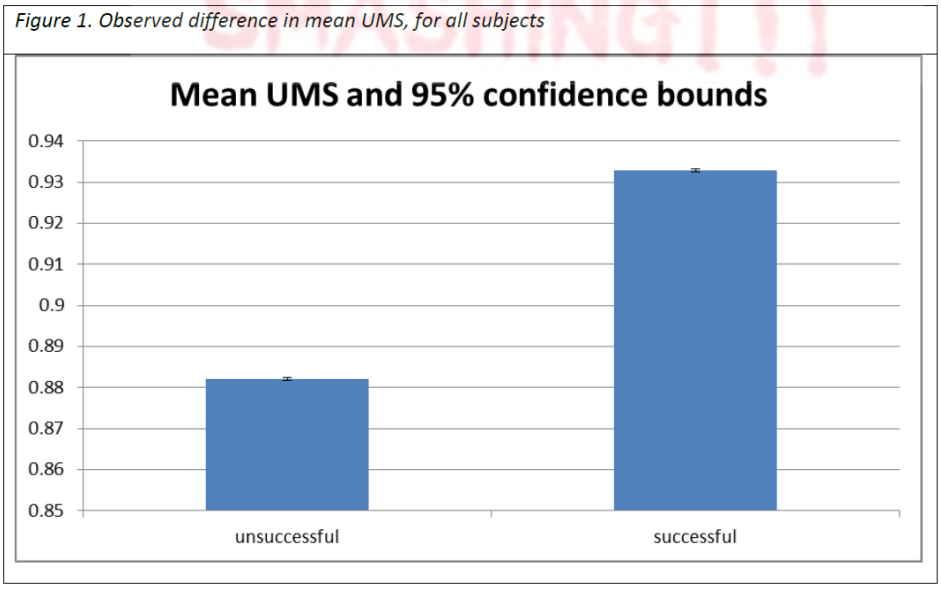
This short paper therefore tests the hypotheses that:

- The UMS attainment of applicants made an offer of a place at Cambridge is significantly higher than those not made the offer of a place, and,
- That this relationship is consistent across all Tripos subjects for which students are admitted, and,
- That differentiation in UMS attainment is consistent across the sector, in that the Cambridge applicants with the highest attainment tend to attend the more selective universities.

This is a report by into students UMS (Uniform Mark Scale, the UK version of PUM, Percentage Uniform Mark score, which is used in international exams like the ones used by CAIE) from their AS levels, which were achieved before they applied to university. The main finding was that the students accepted into the university had on average a UMS score of 93 across all of their subjects, while those rejected had a UMS score of 88. The fact that this study of 40 000 applicants was carried out, and especially because it was published and is still hosted by the university means that this is something they would like the world, and probably also prospective applicants, to know about. They are the only university that asks every student specifically for their UMS/PUM scores.

Another way to think about this is that if you have a lower UMS/PUM score, you probably might rethink Cambridge, and maybe lean more towards Oxford instead.

Figure 1. Observed difference in mean UMS, for all subjects



Analysis of MCQ answer frequencies

Averages

All subjects		s1 & s2%	s1	s2	2020+
A		12.9	12.9	13	11.4
B		14.2	14.3	14	12.2
C		17.2	17.9	16	13.8
D		16.5	18.2	13	12.8
E		17.9	16.2	21	16.9
F		9.8	10.2	9	9.9
G		7.2	6.3	9	8.0
H		4.3	4.0	5	3.9
Totals	1010	100.0			

All subjects	s1 2016SP	%	s1 2016	%	s1 2017	%	s1 2018	%	s1 2019	%	s1 2020sp	%	s1 2020	%	s1 2021	%	s1 2022	%
A	14	16	10	11	11	12	14	16	8	9	12	15	10	13	11	14	9	11
B	14	16	11	12	16	18	11	12	12	13	14	18	9	11	12	15	11	14
C	18	20	20	22	16	18	20	22	17	19	13	16	12	15	11	14	12	15
D	22	24	16	18	17	19	9	10	17	19	20	25	12	15	12	15	15	19
E	13	14	12	13	14	16	20	22	16	18	12	15	10	13	14	18	14	18
F	6	7	9	10	8	9	8	9	9	10	3	4	17	21	11	14	7	9
G	1	1	7	8	4	4	4	4	5	6	4	5	7	9	5	6	11	14
H	2	2	5	6	4	4	4	4	6	7	2	3	3	4	4	5	1	1
Totals	90		90		90		90		90		80		80		80		80	

All subjects	s2 2020sp	%	s2 2020	%	s2 2021	%	s2 2022sp	%	s2 2022	%
A	6	20	5	8	4	7	6	20	6	10
B	3	10	10	17	8	13	5	17	8	13
C	5	17	10	17	11	18	5	17	7	12
D	1	3	14	23	11	18	1	3	11	18
E	9	30	8	13	10	17	8	27	11	18
F	1	3	6	10	7	12	2	7	8	13
G	2	7	5	8	6	10	2	7	7	12
H	3	10	2	3	3	5	1	3	2	3
Totals	30		60		60		30		60	

Chemistry		s1 & s2%	s1	s2	2020+ %
A		13.7	8.0	6.6	11.1
B		13.2	6.1	9.4	13.9
C		17.5	11.0	9.1	13.3
D		18.7	12.2	7.6	13.3
E		20.7	11.7	11.7	18.9
F		9.2	5.6	3.1	10.0
G		4.7	1.2	4.6	6.7
H		2.3	1.2	1.3	1.7
Totals	250	100.0			

Chemistry	s1 2016SP	%	s1 2016	%	s1 2017	%	s1 2018	%	s1 2019	%	s1 2020sp	%	s1 2020	%	s1 2021	%	s1 2022	%
A	4	22	2	11	2	11	4	22	1	6	4	20	1	5	3	15	3	15
B	1	6	0	0	2	11	3	17	3	17	2	10	2	10	3	15	2	10
C	4	22	7	39	2	11	5	28	1	6	4	20	2	10	4	20	3	15
D	3	17	5	28	7	39	2	11	4	22	5	25	4	20	2	10	3	15
E	6	33	1	6	3	17	3	17	4	22	5	25	4	20	5	25	4	20
F	0	0	3	17	1	6	1	6	2	11	0	0	5	25	3	15	2	10
G	0	0	0	0	0	0	0	0	1	6	0	0	2	10	0	0	2	10
H	0	0	0	0	1	6	0	0	2	11	0	0	0	0	0	0	1	5
Totals	18		18		18		18		18		20		20		20		20	

Chemistry	s2 2020sp	%	s2 2020	%	s2 2021	%	s2 2022sp	%	s2 2022	%
A	2	20	1	5	1	5	2	20	3	15
B	1	10	5	25	3	15	2	20	4	20
C	2	20	4	20	4	20	1	10	1	5
D	1	10	3	15	4	20	1	10	4	20
E	3	30	3	15	3	15	3	30	3	15
F	0	0	1	5	3	15	0	0	4	20
G	1	10	2	10	1	5	1	10	1	5
H	0	0	1	5	1	5	0	0	0	0
Totals	10		20		20		10		20	

Numbers of MCQs in Chemistry that have a certain number of answers:

2020+ %	S1 Only	Possible answer #	s1 & s2	
1	1	4	0	# of D
25	34	5	28	# of E
28	33	6	32	# of F
9	5	7	8	# of G
37	27	8	32	# of H
100	100	Totals	100	

	s1 2016SP	%	s1 2016	%	s1 2017	%	s1 2018	%	s1 2019	%	s1 2020sp	%	s1 2020	%	s1 2021	%	s1 2022	%
# of D		0		0		0		0		0	1	5		0		0		0
# of E	13	72	4	22	2	11	4	22	6	33	14	70	3	15	9	45	3	15
# of F	5	28	7	39	9	50	8	44	5	28	5	25	6	30	5	25	6	30
# of G		0	2	11		0	3	17	1	6		0	1	5	1	5	1	5
# of H		0	5	28	7	39	3	17	6	33		0	10	50	5	25	10	50
Totals	18	100	18	100	18	100	18	100	18	100	20	100	20	100	20	100	20	100

	s2 2020sp	%	s2 2020	%	s2 2021	%	s2 2022sp	%	s2 2022	%
# of D		0		0		0		0		0
# of E	1	10	3	15	5	25	1	10	4	20
# of F	3	30	6	30	6	30	3	30	5	25
# of G	1	10	1	5	5	25	1	10	3	15
# of H	5	50	10	50	4	20	5	50	8	40
Totals	10		20		20		10		20	

Biology		s1 & s2%	s1	s2	2020+ %
A		10.7	6.8	5.2	9.4
B		12.7	8.0	6.0	10.0
C		12.6	7.2	7.2	12.2
D		14.5	8.8	5.8	11.7
E		15.2	6.5	12.3	14.4
F		13.7	8.4	6.4	12.8
G		11.7	5.4	6.3	11.7
H		9.0	6.0	4.0	6.7
Totals	250	100.0			

Biology	s1 2016SP	%	s1 2016	%	s1 2017	%	s1 2018	%	s1 2019	%	s1 2020sp	%	s1 2020	%	s1 2021	%	s1 2022	%
A	1	6	1	6	3	17	2	11	2	11	3	15	2	10	4	20	2	10
B	2	11	4	22	3	17	2	11	2	11	3	15	1	5	4	20	3	15
C	1	6	3	17	4	22	1	6	3	17	0	0	4	20	3	15	2	10
D	5	28	2	11	2	11	1	6	4	22	4	20	1	5	4	20	4	20
E	1	6	4	22	1	6	5	28	2	11	2	10	1	5	1	5	1	5
F	5	28	1	6	2	11	3	17	0	0	3	15	7	35	1	5	4	20
G	1	6	1	6	1	6	2	11	2	11	4	20	2	10	1	5	4	20
H	2	11	2	11	2	11	2	11	3	17	1	5	2	10	2	10	0	0
Totals	18		18		18		18		18		20		20		20		20	

Biology	s2 2020sp	%	s2 2020	%	s2 2021	%	s2 2022sp	%	s2 2022	%
A	1	10	3	15	1	5	1	10	1	5
B	0	0	3	15	4	20	1	10	1	5
C	1	10	3	15	2	10	2	20	2	10
D	0	0	5	25	3	15	0	0	4	20
E	4	40	1	5	4	20	3	30	4	20
F	1	10	2	10	2	10	2	20	1	5
G	1	10	2	10	3	15	1	10	5	25
H	2	20	1	5	1	5	0	0	2	10
Totals	10		20		20		10		20	

Major takeaways from this analysis

1. The trends are stronger in chemistry than all, and weaker in biology.
2. In chemistry, 8 answers, a to h, is the most common question type, and about half of Section 2 questions have 8 possible answers. Questions with 8 answers is increasingly common for Section 1.
3. As common as 8 answers are, there is a very low frequency of correct answers that are assigned to answer h, or even, to a lesser extent to g and f.
4. These trends exist across all papers from 2016sp to 2022, as well as for exam papers 2020sp and onwards.
5. A correct answer could be any letter, but seems less likely if it is the first or the last option. So pure guesses at answer e would be optimal if these trends persist. If you had a fifty-fifty feeling for two answers, and one was at the end of the options, maybe go for the other answer.
6. These trends are often found in other MCQ tests, like AS Chemistry offered by CAIE, who also create the NSAA, for instance.

Explained Exam Mark Schemes

The Specimen Paper for 2020 has explained answers for section 1 questions.

The Specimen Paper for 2022 has explained answers for section 2 questions.

Comments on marking and unusual questions

Marking

Sometimes 2 marks was assigned for a single point, or 4 marks were assigned for a single correct number, but the method marks were not clearly described. This implies a style and a creative flair in the marking process that would be hard to find in CAIE or IB mark schemes for such a small sample space. This is for the older short answer section 2 before it became all multiple choice, so a lot less relevant moving ahead.

Unusual Material in Exam Questions

Sometimes topic boundaries are blurred, for instance reactivity from periodicity and electrochemistry.

For section 1 most of the material mapped to AS with electrolysis in A2 Topic 24 being a notable exception.

Basic trigonometry is included with some questions e.g.:

Q# 92/ Cambridge/2022sp/Section 2/ www.SmashingScience.org

19 Bromine trifluoride, BrF_3, is a simple molecular compound containing single bonds only.

It is **not** trigonal planar.

Two of the bond lengths in this molecule are 0.181 nm, and the third is 0.172 nm.

The through-space distances between two fluorine atoms are 0.241 nm or 0.361 nm.

What is the acute bond angle in BrF_3?

A $\sin^{-1}\left(\frac{0.1205}{0.172}\right)$

B $\cos^{-1}\left(\frac{0.1205}{0.172}\right)$

C $\sin^{-1}\left(\frac{0.1205}{0.181}\right)$

D $\cos^{-1}\left(\frac{0.1205}{0.181}\right)$

E $\sin^{-1}\left(\frac{0.172}{0.1805}\right)$

F $\cos^{-1}\left(\frac{0.172}{0.1805}\right)$

G $\sin^{-1}\left(\frac{0.1805}{0.181}\right)$

H $\cos^{-1}\left(\frac{0.1805}{0.181}\right)$

Q# 92/ Cambridge/2022sp/Section 2/ www.SmashingScience.org

19 G

In addition, use of **quadratic equations** is needed for a very small number of equilibrium questions:

From the 2022 to 2024 CAIE A Level Chemistry Syllabus (page 21):

7 use the K_c and K_p expressions to carry out calculations (such calculations will not require the solving of quadratic equations)

A Level Topic # 25x **Q# 264/ Cambridge/2022sp/Section 2/ www.SmashingScience.org**

20 Ethanoic acid, ethanol and water were added to a reaction vessel and a quantity of concentrated sulfuric acid was added. The reaction mixture was then heated and an ester (ethyl ethanoate) and water were formed in equilibrium with the reactants.

$$C_2H_5OH(l) + CH_3COOH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$$

120 g of ethanoic acid and 92 g of ethanol were used and the mass of water present at the start of the experiment was 18 g. Assume that there is no change in volume.

At the temperature of the reaction, the equilibrium constant K_c is 2.00.

What is the mass of the ester present in the mixture at equilibrium?

(M_r values: ethanoic acid = 60; ethanol = 46; water = 18; ethyl ethanoate = 88)

A 1.00 g

B 53.0 g

C 88.0 g

D 103 g

E 106 g

F 176 g

G 209 g

H 215 g

A Level Topic # 25 Q# 265/ Cambridge/2022/Section 2/ www.SmashingScience.org

48 50 cm^3 of 0.100 mol dm^{-3} hydrochloric acid has a pH of 1.0.

What is the pH of the mixture formed when 450 cm^3 of 0.010 mol dm^{-3} calcium hydroxide solution is added?

A pH = 1.0

B 1.0 < pH < 2.0

C pH = 2.0

D 2.0 < pH < 7.0

E pH = 7.0

F pH > 7.0

Q# 264/ Cambridge/2022sp/Section 2/ www.SmashingScience.org

20 C

20 The answer is option **C**.

	CH_3COOH	+	CH_3CH_2OH	⇌	$CH_3COOCH_2CH_3$	+	H_2O
mass at the start	120		92		0		18
M_r	60		46		88		18
number of moles at the start	2		2		0		1
number of moles at equilibrium	$2-x$		$2-x$		x		$1+x$

The equilibrium constant is: $K_c = \dfrac{[CH_3COOCH_2CH_3][H_2O]}{[CH_3COOH][CH_3CH_2OH]}$

Substituting in the number of moles: $K_c = \dfrac{(x)(1+x)}{(2-x)(2-x)} = 2$

Rearranging: $x^2 + x = 2(x^2 - 4x + 4)$

$x^2 + x = 2x^2 - 8x + 8$

$x^2 - 9x + 8 = 0$

Using the quadratic formula: $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \dfrac{-9 \pm \sqrt{9^2 - 32}}{2}$

or by factorising: $(x-8)(x-1) = 0$

$x = 8$ or 1

A value of 8 is impossible because that would require '–6 mol' of reactants.

At equilibrium there would be just one mole of ester, which has a mass of 88 g.

Understanding and knowledge of **ions tests** is needed for a small proportion of questions. All these questions can be found at the start of this book.

41 The following pairs of 0.1 mol dm^{-3} solutions are mixed separately in test tubes.

1 $AgNO_3(aq)$ with NaI(aq)

2 $Cl_2(aq)$ with NaI(aq)

3 HCl(aq) with NaOH(aq)

4 $MgCl_2(aq)$ with NaBr(aq)

Which pair(s) of solutions, when mixed, would produce a visible chemical change?

A 1 only

B 2 only

C 3 only

D 4 only

E 1 and 2 only

F 1 and 3 only

G 2 and 4 only

H 3 and 4 only

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1 $AgNO_3(aq)$ with $NaI(aq)$

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3 $HCl(aq)$ with $NaOH(aq)$

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A 1 only

B 2 only

C 3 only

D 4 only

E 1 and 2 only

F 1 and 3 only

G 2 and 4 only

H 3 and 4 only

47 X is a gaseous element. X can react explosively with hydrogen to produce a single product. When dissolved in water, this product forms an acidic aqueous solution Y. When aqueous silver nitrate is added to solution Y, a white precipitate forms.

Solution Y reacts with substance Z to form two products only. One of these products forms a white precipitate when aqueous sodium hydroxide is added to it.

Which of the following could be X and Z?

	X	*Z*
A	Br_2	$CaCO_3$
B	Br_2	CuO
C	Br_2	Mg
D	Cl_2	$CaCO_3$
E	Cl_2	CuO
F	Cl_2	Mg
G	O_2	$CaCO_3$
H	O_2	Mg

59 A mixture of both sodium nitrate and barium bromide solids, with a combined mass of 6.36 g, was stirred into water and completely dissolved.

An excess of aqueous silver nitrate was added and a precipitate formed. The precipitate was filtered and dried. The mass of dry precipitate was 3.76 g.

What was the mass of sodium nitrate in the original mixture?

(M_r values: $NaNO_3 = 85$; $BaBr_2 = 297$; $AgBr = 188$)

A 0.42 g

B 0.85 g

C 1.70 g

D 2.97 g

E 3.39 g

F 5.94 g

43 Which of the following tests could be used, on its own, to distinguish between all three of the following white solids: potassium carbonate, calcium chloride and sodium sulfate?

1 Add a small amount of each solid separately to a platinum wire and hold in a colourless flame.

2 Dissolve a small amount of each solid separately in deionised water and add a few drops of sodium hydroxide solution.

3 Dissolve a small amount of each solid separately in deionised water and add a few drops of hydrochloric acid, followed by barium chloride solution.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

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3 Dissolve a small amount of each solid separately in deionised water and add a few drops of hydrochloric acid, followed by barium chloride solution.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

52 10 g of a mixture of solid magnesium hydroxide, $Mg(OH)_2$, and solid sodium hydroxide, NaOH, is added to an excess of water and stirred.

One of the components of the mixture dissolves. Assume that the other is completely insoluble.

The mixture is filtered to remove the insoluble component of the mixture.

50 cm^3 of 1.0 mol dm^{-3} sulfuric acid exactly neutralises the remaining solution.

What is the mass of magnesium hydroxide in the original mixture?

(M_r values: $Mg(OH)_2$ = 58; NaOH = 40)

A 2.0 g

B 2.9 g

C 4.0 g

D 5.8 g

E 6.0 g

F 8.0 g

45 X is an anhydrous salt of iron containing one type of cation and one type of anion.

An aqueous solution of X gives a white precipitate when aqueous barium chloride is added in the presence of hydrochloric acid.

On adding aqueous sodium hydroxide to an aqueous solution of X, a brown precipitate formed immediately.

The relative atomic mass of iron is 56, and its atomic number is 26.

What is the relative molar mass of X?

(A_r values: C = 12; N = 14; O = 16; S = 32; Cl = 35.5; Br = 80)

A 127

B 152

C 162.5

D 208

E 264

F 272

G 360

H 400

50 Element Z is in Group 1 of the Periodic Table.

A pure sample of element Z consists of two isotopes with mass numbers 85 and 87, and has a relative atomic mass of 85.5.

Which of the following statements is/are correct about element Z in this sample?

1 Element Z reacts with bromine to form an ionic compound with formula ZBr_2.

2 Element Z forms a basic oxide.

3 More than 70% of the atoms of element Z have mass number 85.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

53 The atomic number of fluorine is 9.

An element X forms a fluoride with the formula XF_3. Each molecule of XF_3 has 32 electrons in total.

Element X has two isotopes. One isotope has the same number of neutrons as protons and the other isotope has a number of neutrons one greater than the number of protons.

The relative abundance of the heavier isotope is 0.80 (80%).

What is the relative atomic mass of element X?

A 5.2

B 5.8

C 10.2

D 10.8

E 14.2

F 14.8

G 16.2

H 16.8

32 The first ionisation energy of five elements is measured.

Which row matches the five elements to their first ionisation energy?

	first ionisation energy / kJ mol^{-1}				
	577	736	1000	1060	1680
A	F	Mg	Al	P	S
B	F	P	S	Mg	Al
C	F	P	S	Al	Mg
D	Mg	Al	S	P	F
E	Mg	Al	P	S	F
F	Al	Mg	P	S	F
G	Al	Mg	S	P	F
H	S	P	Al	Mg	F

42 Consider the following three ions of calcium observed in mass spectrometry:

$^{40}Ca^{2+}$ $^{42}Ca^{2+}$ $^{43}Ca^{+}$

Which of the following statements is/are correct?

1 All three ions have the electron configuration 2,8,8

2 $^{42}Ca^{2+}$ has more neutrons than $^{40}Ca^{2+}$

3 $^{42}Ca^{2+}$ has more protons than $^{43}Ca^{+}$

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

43 The relative isotopic abundances of a sample of magnesium are shown in the table.

isotope	*percentage abundance*
^{24}Mg	80
^{25}Mg	10
^{26}Mg	10

What is the relative atomic mass (A_r) of the magnesium?

A 24.0

B 24.3

C 24.5

D 24.8

E 25.0

56 An element Z forms an ionic compound ZSO_4 which has $M_r = 120.4$

The ion of Z in ZSO_4 has 10 electrons.

Element Z has three isotopes, labelled L, M and N, which contain the following numbers of neutrons.

isotope	L	M	N
number of neutrons	12	13	14

The percentage abundances of isotopes M and N are the same.

What is the percentage abundance of the isotope L in the element Z in ZSO_4?

(M_r value: $SO_4^{2-} = 96.1$)

A 4.10%

B 10.0%

C 13.4%

D 43.3%

E 80.0%

F 91.8%

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(M_r value: $SO_4^{2-} = 96.1$)

A 4.10%

B 10.0%

C 13.4%

D 43.3%

E 80.0%

F 91.8%

42 A simple ion of an element with atomic number x has a mass number of $(2x + 2)$.

The ion has a charge of –2.

How many protons, neutrons and electrons are present in this ion?

	protons	*neutrons*	*electrons*
A	$x - 2$	$x + 4$	$x - 2$
B	$x - 2$	$x + 4$	x
C	$x - 2$	$x + 4$	$x + 2$
D	x	$x + 2$	$x - 2$
E	x	$x + 2$	x
F	x	$x + 2$	$x + 2$

37 Which row in the following table gives the numbers of protons, neutrons and electrons in $^{64}_{29}Cu^{2+}$?

	number of protons	*number of neutrons*	*number of electrons*
A	27	33	27
B	27	35	29
C	29	35	27
D	29	35	29
E	31	33	29
F	31	35	29

37 Consider the atoms/ions below:

$^{24}_{12}Mg^{2+}$ $^{16}_{8}O^{2-}$ $^{18}_{8}O$ $^{32}_{16}S^{2-}$

Which of the following statements is/are correct?

1 Both $^{16}_{8}O^{2-}$ and $^{24}_{12}Mg^{2+}$ have the same electronic configuration.

2 $^{32}_{16}S^{2-}$ has double the number of neutrons that are in $^{18}_{8}O$.

3 The sum of the numbers of electrons in $^{16}_{8}O^{2-}$ and $^{18}_{8}O$ is equal to the number of electrons in $^{32}_{16}S^{2-}$.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

54 An atom of $^{1}_{1}H$ has a radius of 0.05 nanometres.

The radius of the nucleus of this atom is approximately 50 000 times smaller.

What is the approximate radius of the nucleus in femtometres?

(1 femtometre = 10^{-15} m)

A 1000

B 100

C 10

D 1

E 0.1

F 0.01

37 Which one of the following atoms or ions contains the same number of neutrons and electrons as $^{40}_{20}Ca^{2+}$?

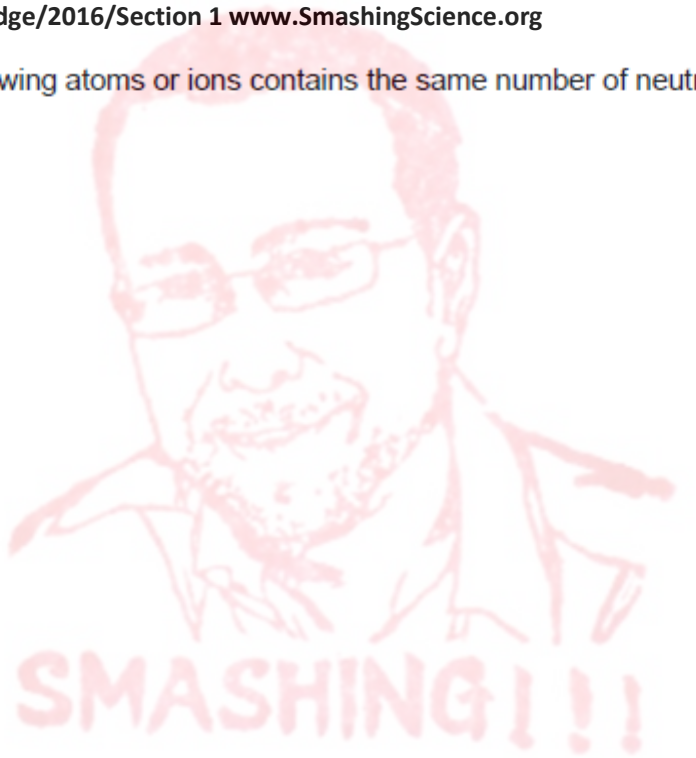
A $^{35}_{17}Cl^{-}$

B $^{37}_{17}Cl$

C $^{40}_{18}Ar$

D $^{39}_{19}K^{+}$

E $^{39}_{19}K$



14 Thionyl chloride, $SOCl_2$, is the only product of the reaction between sulfur trioxide, chlorine and sulfur dichloride.

Thionyl chloride reacts with water to make hydrogen chloride and one other gaseous product, which is triatomic.

2.0 dm^3 of chlorine gas (measured at room temperature and pressure) was reacted completely with sulfur trioxide and sulfur dichloride.

The product was isolated, dissolved in water and made up to 200 cm^3.

What is the maximum concentration of HCl in the resulting solution?

(Assume that one mole of gas at room temperature and pressure occupies 24 dm^3.)

A 0.28 $mol\,dm^{-3}$

B 0.50 $mol\,dm^{-3}$

C 0.83 $mol\,dm^{-3}$

D 1.25 $mol\,dm^{-3}$

E 2.50 $mol\,dm^{-3}$

F 5.00 $mol\,dm^{-3}$

17 In 1836, James Marsh devised a test to allow the detection of very small traces of arsenic.

The first stage of the Marsh test involves the reaction of arsenic trioxide, As_2O_3, with zinc under acidic conditions. One of the products is compound X.

The **unbalanced** equation for the reaction is:

$$As_2O_3(s) + Zn(s) + H^+(aq) \rightarrow X(g) + Zn^{2+}(aq) + H_2O(l)$$

In the **balanced** equation, 1.0 mol of arsenic trioxide reacts with 6.0 mol of zinc, and produces 2.0 mol of X and 6.0 mol of zinc ions. Only the zinc and the arsenic change oxidation state in this reaction.

If 1.98 g of arsenic trioxide reacts with an excess of zinc and acid in this reaction, what is the maximum mass of X that could be produced?

(A_r values: H = 1; O = 16; Zn = 65; As = 75)

A 0.39 g

B 0.75 g

C 0.78 g

D 1.50 g

E 1.56 g

F 1.66 g

53 The atomic number of fluorine is 9.

An element X forms a fluoride with the formula XF_3. Each molecule of XF_3 has 32 electrons in total.

Element X has two isotopes. One isotope has the same number of neutrons as protons and the other isotope has a number of neutrons one greater than the number of protons.

The relative abundance of the heavier isotope is 0.80 (80%).

What is the relative atomic mass of element X?

A 5.2

B 5.8

C 10.2

D 10.8

E 14.2

F 14.8

G 16.2

H 16.8

58 An oxide of nitrogen can be prepared by the reaction of copper with hot nitric acid.

The other products of the reaction are copper(II) nitrate and water.

0.060 mol of copper reacted exactly with 40.0 cm^3 of 4.00 mol dm^{-3} nitric acid.

What is the empirical formula of the oxide of nitrogen produced in the reaction?

A NO

B NO_2

C NO_3

D N_2O

E N_2O_3

F N_2O_5

55 The equation shows the complete combustion of an alkane.

$$\text{alkane} + a\text{O}_2 \rightarrow b\text{CO}_2 + c\text{H}_2\text{O}$$

100 cm^3 of a gaseous alkane requires 650 cm^3 of oxygen for complete combustion. The volumes of both gases were measured at the same temperature and pressure.

What is the value of $a + b + c$?

A 10.5

B 12

C 14

D 15.5

E 17.5

F 19

58 An oxide of nitrogen can be prepared by the reaction of copper with hot nitric acid.

The other products of the reaction are copper(II) nitrate and water.

0.060 mol of copper reacted exactly with 40.0 cm^3 of 4.00 mol dm^{-3} nitric acid.

What is the empirical formula of the oxide of nitrogen produced in the reaction?

A NO

B NO_2

C NO_3

D N_2O

E N_2O_3

F N_2O_5

21 A Group 1 metal hydrogencarbonate contains the HCO_3^- ion and decomposes at 200 °C.

When dilute hydrochloric acid is added to the residue from the thermal decomposition of this metal hydrogencarbonate, a gas is released that turns limewater cloudy. The residue also gives a yellow-orange colour in a flame test.

8.4 g of this metal hydrogencarbonate is heated to constant mass at 200 °C.

How much mass is lost in this reaction?

(A_r values: H = 1; C = 12; O = 16; Li = 7; Na = 23; K = 39)

A 2.2 g

B 2.6 g

C 3.1 g

D 4.0 g

E 4.4 g

F 5.3 g

G 6.2 g

24 A sample of hydrated cobalt(II) sulfate, $CoSO_4 \cdot xH_2O$, with a mass of 5.62 g, was heated to convert the sample completely to 3.10 g of anhydrous cobalt(II) sulfate.

What is the value of x?

(A_r values: H = 1.0; O = 16.0; S = 32.1; Co = 58.9)

A 2

B 3

C 4

D 5

E 6

F 7

G 8

H 9

30 Iron(II) sulfate is used as a moss treatment on lawns and sports pitches. The recommended amount of iron is 2.5 kg per 10^4 m^2.

Analysis of a particular sports pitch showed it to contain 0.05 g of iron per m^2.

A pitch care company supplies three hydrated formulations:

- $FeSO_4 \cdot 7H_2O$ which contains 20% of iron by mass
- $FeSO_4 \cdot 4H_2O$ which contains 25% of iron by mass
- $FeSO_4 \cdot H_2O$ which contains 33% of iron by mass

A 25 kg sack of one of the iron(II) sulfate formulations is to be used on the sports pitch but unfortunately it has lost its label. A small sample was heated to constant mass to form a white solid, and the mass of the sample decreased by more than 40% in this process.

The sports pitch is 90 m long and 60 m wide.

What mass of the iron(II) sulfate formulation (in kg) should be added to ensure that the iron content is at the recommended level?

(M_r values: $FeSO_4$ = 152; H_2O = 18)

A 1.08 kg

B 1.35 kg

C 3.60 kg

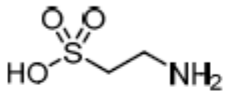
D 4.32 kg

E 5.40 kg

F 6.75 kg

37 Cats are unable to synthesise the amino acid taurine in their bodies, so they must obtain it from their food. It is often added to cat food as an additive.

Taurine is a monoprotic acid with the following molecular structure:



$M_r = 125$

Dietary studies suggest that a cat should consume 10 mg of taurine per kilogram of body mass per day.

Brand X cat food contains taurine at a level of 0.008% by mass, but this level is too low for a cat to acquire a sufficient amount from a healthy amount of food.

Magnesium taurate is an ionic salt which liberates taurine in the body. 8 cm^3 of a 0.5 mol dm^{-3} aqueous solution of magnesium taurate was added to a 10 kg bag of brand X cat food and thoroughly mixed.

A particular cat bowl can hold a 50 g serving of cat food. A particular cat of mass 4000 g always eats a full serving.

What is the minimum number of bowls of cat food that this cat must eat to ensure that it has consumed its daily requirement of taurine?

(Assume that the addition of the solution does not significantly alter the total mass of the bag of cat food.)

A 2

B 3

C 4

D 5

E 6

F 7

G 8

40 Consider the following chemical equation:

$$v\text{Q} + w\text{P}_4 + x\text{H}_2\text{O} \rightarrow y\text{PH}_4\text{I} + z\text{H}_3\text{PO}_4$$

where Q is a binary compound.

The molecules of Q are hexatomic and contain phosphorus in the +2 oxidation state.

Using the lowest integer values for all the coefficients v, w, x, y and z, what is the value of w when the equation is balanced?

A 1

B 2

C 13

D 16

E 24

F 26

50 Chlorine gas reacts with hot concentrated aqueous sodium hydroxide to form sodium chloride, sodium chlorate(V) and water.

The **unbalanced** ionic equation for this reaction is:

$$u\text{Cl}_2 + v\text{OH}^- \rightarrow w\text{Cl}^- + x\text{ClO}_3^- + y\text{H}_2\text{O}$$

What is the simplest ratio of $w:x$ in the balanced equation?

A 1 : 1

B 1 : 2

C 2 : 1

D 1 : 5

E 5 : 1

F 1 : 7

G 7 : 1

52 A reaction between copper and nitric acid produces a blue solution of copper(II) nitrate, water and substance X only.

Substance X does not contain copper or hydrogen.

The balanced equation for the reaction shows that 1 mole of copper reacts to produce 2 moles of water.

What is the identity of substance X?

A N_2

B NO

C NO_2

D NO_3

E N_2O_5

14 Thionyl chloride, $SOCl_2$, is the only product of the reaction between sulfur trioxide, chlorine and sulfur dichloride.

Thionyl chloride reacts with water to make hydrogen chloride and one other gaseous product, which is triatomic.

2.0 dm^3 of chlorine gas (measured at room temperature and pressure) was reacted completely with sulfur trioxide and sulfur dichloride.

The product was isolated, dissolved in water and made up to 200 cm^3.

What is the maximum concentration of HCl in the resulting solution?

(Assume that one mole of gas at room temperature and pressure occupies 24 dm^3.)

A 0.28 mol dm^{-3}

B 0.50 mol dm^{-3}

C 0.83 mol dm^{-3}

D 1.25 mol dm^{-3}

E 2.50 mol dm^{-3}

F 5.00 mol dm^{-3}

15 Tollens' reagent, $[Ag(NH_3)_2]NO_3(aq)$, can be used to coat glass surfaces with silver metal (A_r = 108) to make decorative objects. It is a reducing agent and reacts by oxidising aldehydes to carboxylic acids.

The half-equation for the organic oxidation can be represented as (R = alkyl group):

$$\underset{\text{aldehyde}}{RCHO} + H_2O \rightarrow \underset{\substack{\text{carboxylic}\\\text{acid}}}{RCOOH} + 2H^+ + 2e^-$$

All of the inside surface of a beaker is to be coated in a uniform layer of silver metal of thickness 0.01 cm. The beaker can be modelled as a cylinder of height 10 cm and radius 5 cm.

The density of silver metal is 10.5 g cm^{-3}.

Which of the following expressions gives the minimum number of moles of aldehyde required?

(Assume that the yield of any reaction is 100%.)

A $\dfrac{10.5 \times 1.25 \times \pi}{2 \times 108}$

B $\dfrac{10.5 \times 1.25 \times \pi}{108}$

C $\dfrac{2 \times 10.5 \times 1.25 \times \pi}{108}$

D $\dfrac{108 \times 10.5 \times 1.25 \times \pi}{2}$

E $\dfrac{10.5 \times 1.5 \times \pi}{2 \times 108}$

F $\dfrac{2 \times 10.5 \times 1.5 \times \pi}{108}$

G $\dfrac{10.5 \times 1.5 \times \pi}{108}$

H $\dfrac{108 \times 10.5 \times 1.5 \times \pi}{2}$

17 In 1836, James Marsh devised a test to allow the detection of very small traces of arsenic.

The first stage of the Marsh test involves the reaction of arsenic trioxide, As_2O_3, with zinc under acidic conditions. One of the products is compound X.

The **unbalanced** equation for the reaction is:

$$As_2O_3(s) + Zn(s) + H^+(aq) \rightarrow X(g) + Zn^{2+}(aq) + H_2O(l)$$

In the **balanced** equation, 1.0 mol of arsenic trioxide reacts with 6.0 mol of zinc, and produces 2.0 mol of X and 6.0 mol of zinc ions. Only the zinc and the arsenic change oxidation state in this reaction.

If 1.98 g of arsenic trioxide reacts with an excess of zinc and acid in this reaction, what is the maximum mass of X that could be produced?

(A_r values: H = 1; O = 16; Zn = 65; As = 75)

A 0.39 g

B 0.75 g

C 0.78 g

D 1.50 g

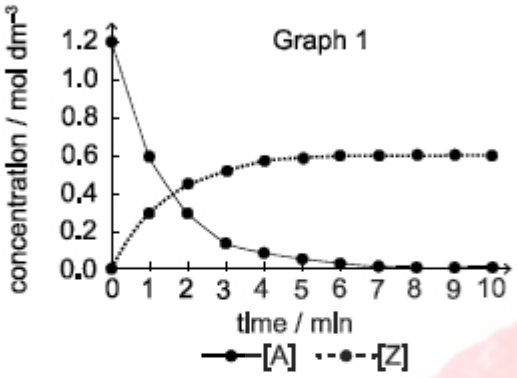
E 1.56 g

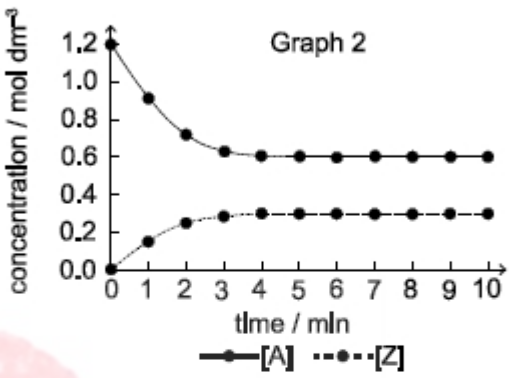
F 1.66 g

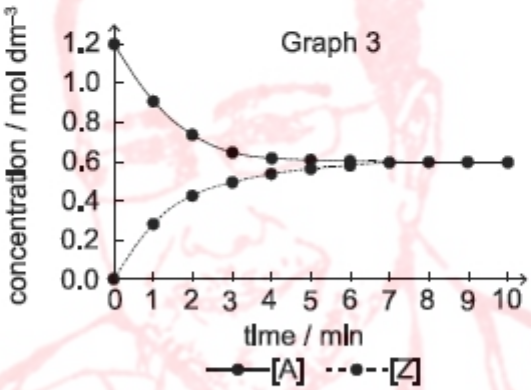
44 Chemicals A and B react to form products Y and Z. The reaction goes to completion. The equation for the reaction is:

$$2A(aq) + B(aq) \rightarrow Y(aq) + Z(aq)$$

Equimolar samples of A and B were mixed and the concentrations of A and Z were measured over time. Which of the following graphs could represent this reaction?







A Graph 1 only

B Graph 2 only

C Graph 3 only

D Graphs 1 and 2 only

E Graphs 2 and 3 only

A Level Topic # **2 Q# 39/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org**

45 An oxide of iron has the formula Fe_3O_4 and contains both Fe^{2+} and Fe^{3+} ions.

Which one of the following is the fraction of iron ions that are in the Fe^{2+} state?

A $\frac{1}{4}$

B $\frac{1}{3}$

C $\frac{1}{2}$

D $\frac{2}{3}$

E $\frac{3}{4}$

A Level Topic # **2 Q# 40/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org**

49 What volume of water vapour measured at room temperature and pressure would be produced from an ice cube of mass 6.00 g if it all evaporated?

(A_r values: H = 1; O = 16. Molar volume of a gas at room temperature and pressure = 24 dm^3)

A 240 cm^3

B 1800 cm^3

C 4800 cm^3

D 8000 cm^3

E 24 000 cm^3

A Level Topic # **2 Q# 41/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org**

50 A compound of iodine and oxygen contains 63.5 g of iodine and 20.0 g of oxygen.

Which one of the following is its empirical formula?

(A_r values: I = 127; O = 16)

A IO

B IO_2

C I_2O

D I_2O_3

E I_2O_5

F I_5O_2

52 Naturally occurring chlorine is a mixture of two isotopes with mass number 35 and 37. The isotope with mass number 35 is three times as common as the isotope with mass number 37.

Naturally occurring bromine is a mixture of two isotopes with mass numbers 79 and 81. They are present in equal amounts.

What fraction of the naturally occurring compound CH_2BrCl has a relative molecular mass of 128?

(A_r values: H = 1; C = 12)

A $\frac{1}{8}$

B $\frac{1}{4}$

C $\frac{3}{8}$

D $\frac{1}{2}$

E $\frac{5}{8}$

54 Carbon, in the form of coke, is used to reduce iron oxide in a blast furnace. The three stages are shown below:

1 $C + O_2 \rightarrow CO_2$

2 $CO_2 + C \rightarrow 2CO$

3 $3CO + Fe_2O_3 \rightarrow 2Fe + 3CO_2$

If 12 g of carbon is used in stage 2 and all the carbon monoxide produced is used in stage 3, what mass of carbon dioxide is produced in stage 3?

(A_r values: C = 12; O = 16)

A 17.8 g

B 35.6 g

C 44 g

D 88 g

E 132 g

56 An impure sample of sodium hydroxide has a mass of 1.20 g. All the sodium hydroxide completely reacts with a minimum of 50.0 cm^3 of 0.50 mol dm^{-3} hydrochloric acid.

What is the percentage purity of the sodium hydroxide sample?

(A_r values: H = 1; O = 16; Na = 23; Cl = 35.5)

A 37.5%

B 41.6%

C 72.7%

D 75.0%

E 83.3%

F 90.4%

57 A sample of an alkali XOH of mass 2.8 g was dissolved in water.

This solution was neutralised by 12.5 cm^3 of sulfuric acid of concentration 2.0 mol dm^{-3}.

$$2XOH(aq) + H_2SO_4(aq) \rightarrow X_2SO_4(aq) + 2H_2O(l)$$

What is the relative atomic mass of X?

(A_r values: H = 1; O = 16; S = 32)

A 13

B 26

C 39

D 52

E 65

F 78

58 The equation summarises the reaction of copper and dilute nitric acid.

$$Cu + r HNO_3 \rightarrow Cu(NO_3)_2 + s H_2O + t NO_2$$

What values of s and t are needed to balance the equation?

	s	t
A	1	1
B	2	1
C	4	1
D	2	2
E	4	2

59 Complete combustion of 35 cm^3 of a straight-chain alkane vapour gave 105 cm^3 of carbon dioxide gas. Both gas volumes were measured at the same temperature and pressure.

Which of the following is the molecular formula of the alkane?

A C_2H_4

B C_2H_6

C C_3H_6

D C_3H_8

E C_4H_{10}

45 Iodic acid, HIO_3, can be made from iodine in the following reaction:

$$I_2 + w H_2O + x Cl_2 \rightarrow y HIO_3 + z HCl$$

What is the value of x when the equation is balanced?

A 1

B 2

C 3

D 4

E 5

F 6

46 Which one of the following formulae is correct for the compound given?

A aluminium sulfate, $Al(SO_4)_3$

B ammonium carbonate, $(NH_4)_2CO_3$

C calcium hydroxide, $CaOH$

D magnesium nitrate, $MgNO_3$

E potassium bromide, KBr_2

52 10 g of a mixture of solid magnesium hydroxide, $Mg(OH)_2$, and solid sodium hydroxide, NaOH, is added to an excess of water and stirred.

One of the components of the mixture dissolves. Assume that the other is completely insoluble.

The mixture is filtered to remove the insoluble component of the mixture.

50 cm^3 of 1.0 mol dm^{-3} sulfuric acid exactly neutralises the remaining solution.

What is the mass of magnesium hydroxide in the original mixture?

(M_r values: $Mg(OH)_2 = 58$; $NaOH = 40$)

A 2.0 g

B 2.9 g

C 4.0 g

D 5.8 g

E 6.0 g

F 8.0 g

60 X is a solution of sulfuric acid.

$20.0\,cm^3$ of X is diluted by adding distilled water to produce $500\,cm^3$ of solution Y.

$10.0\,cm^3$ of Y is exactly neutralised by $40.0\,cm^3$ of $0.0500\,mol\,dm^{-3}$ aqueous potassium hydroxide.

What is the concentration of sulfuric acid in X?

A $0.00100\,mol\,dm^{-3}$

B $0.100\,mol\,dm^{-3}$

C $0.200\,mol\,dm^{-3}$

D $0.400\,mol\,dm^{-3}$

E $1.25\,mol\,dm^{-3}$

F $2.50\,mol\,dm^{-3}$

G $5.00\,mol\,dm^{-3}$

H $10.0\,mol\,dm^{-3}$

44 Molecule J is a straight-chain hydrocarbon containing one carbon-carbon double bond.

The relative atomic mass (A_r) of hydrogen is 1 and carbon is 12.

What is the **minimum** additional information that is needed in order to determine the molecular formula of molecule J?

1 The percentage by mass of carbon in the molecule.

2 The percentage by mass of hydrogen in the molecule.

3 The relative molar mass (M_r) of the molecule.

A 1 only

B 3 only

C 1 and 2 only

D 1 and 3 only

E 1, 2 and 3

A Level Topic # **2 Q# 53/ Cambridge/2020/Section 1 www.SmashingScience.org**

45 Iodic acid, HIO_3, can be made from iodine in the following reaction:

$$I_2 + wH_2O + xCl_2 \rightarrow yHIO_3 + zHCl$$

What is the value of x when the equation is balanced?

A 1

B 2

C 3

D 4

E 5

F 6

A Level Topic # **2 Q# 54/ Cambridge/2020/Section 1 www.SmashingScience.org**

46 Which one of the following formulae is correct for the compound given?

A aluminium sulfate, $Al(SO_4)_3$

B ammonium carbonate, $(NH_4)_2CO_3$

C calcium hydroxide, $CaOH$

D magnesium nitrate, $MgNO_3$

E potassium bromide, KBr_2

A Level Topic # **2 Q# 55/ Cambridge/2020/Section 1 www.SmashingScience.org**

55 Complete combustion of 1 mol of hydrocarbon X requires exactly 8.5 mol of oxygen.

Incomplete combustion of 1 mol of hydrocarbon X, to form carbon monoxide and water only, requires exactly 5.5 mol of oxygen.

How many hydrogen atoms are there in one molecule of hydrocarbon X?

A 6

B 8

C 10

D 12

E 14

57 An experiment is carried out using the first three metals in Group 1: lithium, sodium and potassium.

The initial masses of three open beakers each containing 100 g samples of an alcohol are recorded.

In three separate experiments, equal small masses of lithium, sodium and potassium are added to the three beakers, which are on electronic balances.

Each metal reacts in a similar way and after the reaction is complete, the final mass of each beaker and its contents is recorded.

In each case, the final mass of the beaker and its contents is compared to the recorded initial mass before the alkali metal was added.

Which of the following statements is correct?

A The beaker with lithium added would decrease in mass the most.

B The beaker with sodium added would decrease in mass the most.

C The beaker with potassium added would decrease in mass the most.

D All three beakers would show the same decrease in mass.

E The beaker with lithium added would increase in mass the most.

F The beaker with sodium added would increase in mass the most.

G The beaker with potassium added would increase in mass the most.

H All three beakers would show the same increase in mass.

A Level Topic # **2x Q# 57/ Cambridge/2019/Section 2/ www.SmashingScience.org**

Question C1

Data: Assume that the molar gas volume = 24.0 $dm^3 mol^{-1}$ at room temperature and pressure (rtp).

This question concerns the chemistry of tellurium, an element in Group 16 of the Periodic Table.

Tellurium reacts directly with fluorine gas to form a dense gas, **A**, in which each molecule contains a single tellurium atom bonded to several fluorine atoms. In an experiment, 50 cm^3 of gas **A** is formed from 150 cm^3 of fluorine and a certain mass of tellurium, with all measurements made at room temperature and pressure.

d) Calculate the formula of the gas **A**.

[2 marks]

Answer: .....

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e) Predict the value(s) of the F–Te–F bond angles in **A**.

[1 mark]

Answer: .....

f) Calculate the minimum mass of tellurium needed to produce 50 cm^3 of **A**.

[2 marks]

Answer: .....

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g) Calculate the density of gas **A** in g cm^{-3} at room temperature and pressure.

[2 marks]

Answer: .....

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h) Calculate how many times denser gas **A** is than oxygen gas at room temperature and pressure.

[1 mark]

Answer: .....

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In another experiment, 5.0 g of tellurium is oxidised and dissolved in water to form 9.0 g of an acid with general formula H_mTeO_n. On neutralisation with aqueous KOH, 18 g of a salt is formed with general formula K_mTeO_n.

i) Give an expression, in terms of m and n, for the oxidation state of the tellurium in the acid H_mTeO_n.

[1 mark]

Answer: .....

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j) Calculate the relative molecular mass of the acid H_mTeO_n.

[1 mark]

Answer: .....

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k) Calculate the values of m and n, and hence the formulae of the acid H_mTeO_n and the salt formed on neutralisation.

[2 marks]

Answer: .....

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l) Calculate the volume of a 2.0 mol dm^{-3} aqueous solution of KOH that would be needed to neutralise the 9.0 g of acid formed from 5.0 g of tellurium.

[2 marks]

Answer: .....

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A Level Topic # **2 Q# 58/ Cambridge/2019/Section 1 www.SmashingScience.org**

43 A 116 g sample of an oxide of iron contains 84 g of iron.

Which of the following is the empirical formula of this oxide of iron?

(A_r values: O = 16; Fe = 56)

A FeO

B Fe_2O_2

C Fe_3O_2

D Fe_2O_3

E Fe_3O_4

A Level Topic # **2 Q# 59/ Cambridge/2019/Section 1 www.SmashingScience.org**

47 0.005 mol of a chloride of element X was dissolved in water and then reacted with excess silve nitrate solution to form a precipitate of silver chloride, AgCl. This precipitate is the only product of this reaction that contains chlorine.

After filtering, washing and drying, the mass of the precipitate was recorded to be 1.435 g.

Which of the following could be the formula of the chloride of X?

(M_r value: AgCl = 143.5)

A X_5Cl

B X_2Cl

C XCl

D XCl_2

E XCl_5

A Level Topic # **2 Q# 60/ Cambridge/2019/Section 1 www.SmashingScience.org**

48 A chemical equation that represents the reaction of phosphorus with concentrated nitric acid is:

$$P_4 + w\,HNO_3 + H_2O \rightarrow x\,H_3PO_4 + y\,NO + z\,NO_2$$

What is the value of the sum $w + x + y + z$?

A 24

B 28

C 30

D 32

E 36

52 3.4 g of an impure sample of silicon tetrachloride is reacted with water. The mixture is then filtered and the resulting solution made up to 250 cm^3.

$$SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl(aq)$$

12.5 cm^3 of this solution is neutralised exactly by 20.0 cm^3 of 0.100 mol dm^{-3} sodium hydroxide.

What is the percentage purity of the silicon tetrachloride?

(M_r value: $SiCl_4$ = 170. Assume that the impurity does not react.)

A 1.7%

B 2.5%

C 10%

D 32%

E 50%

Question C2

a) Write a balanced chemical equation for the reaction between $CO_2(g)$ and $OH^-(aq)$, giving $CO_3^{2-}(aq)$ as one of the products.

[1 mark]

Answer: .....

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b) An organic molecule is known to contain C, H and O only. A sample of mass 0.100 g is carefully burnt in the presence of excess oxygen. The resulting gases are passed over a desiccant (drying agent), and it is observed that the mass of the desiccant increases by 0.0931 g.

After passing through the desiccant the gases are bubbled through 25.0 cm^3 of a solution of 1.00 mol dm^{-3} NaOH. The solution is then titrated against 1.00 mol dm^{-3} HCl, and the end point is found to be when 14.7 cm^3 of the acid has been added.

(i) Calculate the amount in moles of H_2O produced by the combustion.

[2 marks]

Answer: .....

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(ii) Calculate the amount in moles of CO_2 absorbed by the NaOH solution.

[4 marks]

Answer: .....

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(iii) Hence determine the empirical formula of the organic molecule.

[6 marks]

Answer: .....

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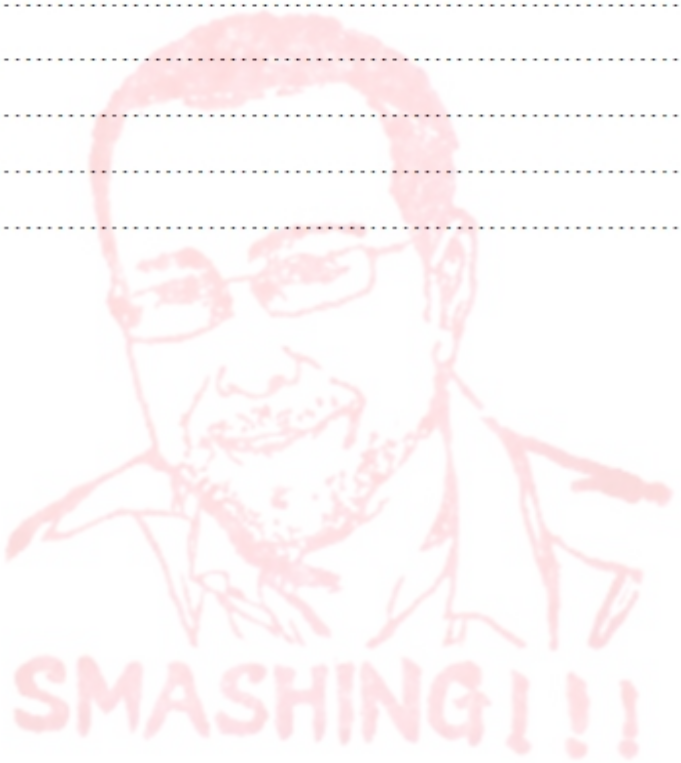

d) The reaction between dimethylglyoxime and Ni^{2+} ions can be used to determine the nickel content of alloys by weighing the amount of the red precipitate produced from a known mass of a sample of an alloy.

A sample of mass 1.50 g of an alloy was dissolved in dilute acid and an excess of dimethylglyoxime was then added to the resulting solution. The pH was then adjusted to make the solution mildly alkaline, and this resulted in the formation of a red precipitate. The precipitate was carefully filtered off, dried and then weighed. The mass of the dry precipitate was 0.368 g.

Determine the nickel content of the alloy, expressed as a percentage by mass.

[4 marks]

Answer: .....

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e) Other metal ions, such as Pd^{2+} or Pt^{2+}, also react with dimethylglyoxime to give insoluble precipitates. What effect would the presence of palladium in the alloy have on the value of the nickel content determined using the method in part **d)**?

[2 marks]

Answer: .....

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47 A student calculated the mass of anhydrous copper(II) sulfate ($CuSO_4$) required to make 250 cm^3 of an aqueous solution of concentration 0.200 mol dm^{-3}.

However, the student mistakenly made the solution using the same mass of hydrated copper(II) sulfate ($CuSO_4 \cdot 5H_2O$) instead.

What is the concentration, in mol dm^{-3}, of the solution made with the hydrated copper(II) sulfate?

(A_r values: Cu = 64; S = 32; O = 16; H = 1.0)

A 0.128 mol dm^{-3}

B 0.160 mol dm^{-3}

C 0.180 mol dm^{-3}

D 0.200 mol dm^{-3}

E 0.223 mol dm^{-3}

F 0.313 mol dm^{-3}

51 Copper can react with concentrated nitric acid to form the gas nitrogen monoxide.

$$3Cu + a\,HNO_3 \rightarrow b\,Cu(NO_3)_2 + c\,H_2O + d\,NO$$

What is the value of a when the equation is balanced?

A 6

B 7

C 8

D 9

E 10

F 11

G 12

52 A small amount of a solid mixture, containing calcium carbonate and an inert substance, was added to 50.00 cm^3 dilute hydrochloric acid of concentration 0.1000 mol dm^{-3}.

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$$

After all of the calcium carbonate had reacted, the solution was heated to drive off the carbon dioxide.

The resulting solution was neutralised by 12.50 cm^3 of 0.1000 mol dm^{-3} sodium hydroxide solution.

What was the mass of calcium carbonate in the mixture added to the hydrochloric acid?

(M_r value: $CaCO_3$ = 100.0)

A 0.06250 g

B 0.1250 g

C 0.1875 g

D 0.3750 g

E 0.6250 g

F 0.7500 g

53 2.80 g of lithium metal is placed in a closed system with 1.20 dm^3 of pure oxygen gas (volume measured at room temperature and pressure).

If a complete reaction occurs between the lithium and the oxygen, what is the maximum mass of lithium oxide that can be formed?

(A_r values: Li = 7; O = 16. Assume that one mole of gas occupies 24.0 dm^3 at room temperature and pressure.)

A 1.50 g

B 3.00 g

C 3.90 g

D 4.60 g

E 6.00 g

F 12.0 g

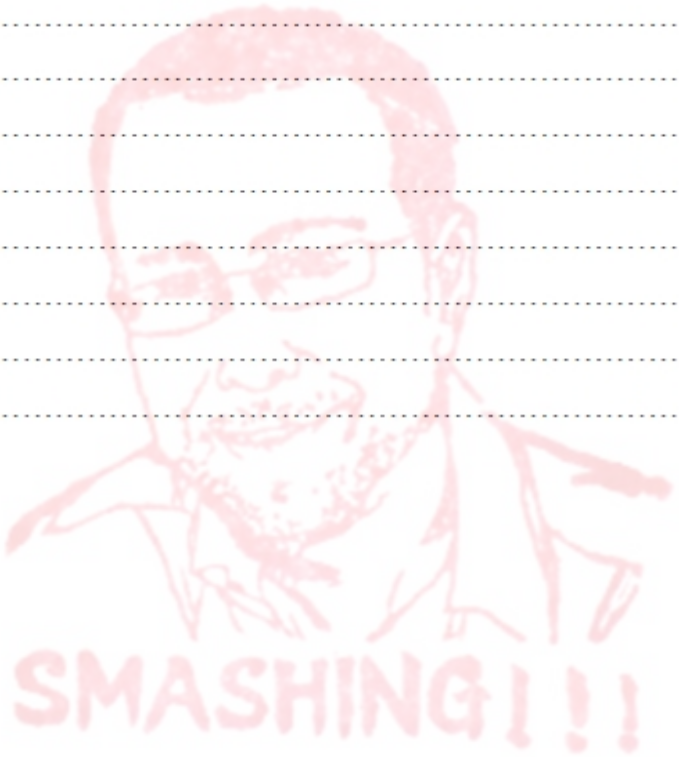
G 15.6 g

b) Substance **A** reacts with aluminium chloride to form lithium aluminium hydride ($LiAlH_4$) and one other by-product.

c) When 3.8 g of lithium aluminium hydride is heated to 125 °C, it decomposes to give three substances: 1.8 g of aluminium metal, 2.4 dm^3 of a flammable gas (measured at rtp), and substance **B**.

Determine the formula for substance **B**. **[5 marks]**

Answer: .....



Question C1

Data: Assume that the molar gas volume = 24.0 $dm^3 mol^{-1}$ at room temperature and pressure (rtp).

a) When lithium metal and hydrogen gas are heated together, a single substance, **A**, is formed as colourless crystals with a melting point of 688 °C. Molten **A** conducts electricity, and electrolysis of the molten substance re-forms the elements.

(i) Give an equation for the formation of **A**. **[1 mark]**

Answer: .....

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(ii) Classify the structure of **A** as either molecular covalent, giant covalent, or ionic. Briefly justify your answer. **[2 marks]**

Answer: .....

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(iii) During the electrolysis of molten **A**, which element appears at the positive electrode (the anode) and which appears at the negative electrode (the cathode)? **[1 mark]**

Answer: .....

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b) Substance **A** reacts with aluminium chloride to form lithium aluminium hydride ($LiAlH_4$) and one other by-product.

Give a balanced chemical equation for the formation of lithium aluminium hydride from **A** and aluminium chloride. **[2 marks]**

Answer: .....

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46 A fluorocarbon has a relative molecular mass which is twice that of its empirical formula mass

81 g of the compound contains 57 g of fluorine.

What is the molecular formula of the compound?

(A_r values: C = 12; F = 19)

A C_2F_3

B C_2F_5

C C_3F_6

D C_3F_8

E C_4F_6

F C_4F_{10}

47 In which of the following reactions is there a change in volume of 24 dm^3, when measured at room temperature and pressure?

1 56 g of carbon monoxide completely reacts with an excess of oxygen
$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$

2 36 g of steam is fully decomposed
$2H_2O(g) \rightarrow 2H_2(g) + O_2(g)$

3 30 g of nitrogen monoxide completely reacts with an excess of oxygen
$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

(A_r values: C = 12; O = 16; H = 1.0; N = 14. Assume that one mole of gas occupies a volume of 24 dm^3 at room temperature and pressure.)

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

52 Natural samples of copper contain two isotopes: ^{63}Cu which has a relative isotopic mass of 62.93, and ^{65}Cu which has a relative isotopic mass of 64.93.

The relative atomic mass of a sample of elemental copper is 63.55.

What is the percentage abundance of each of the two isotopes to the nearest whole number?

A 27% ^{63}Cu and 73% ^{65}Cu

B 73% ^{63}Cu and 27% ^{65}Cu

C 31% ^{63}Cu and 69% ^{65}Cu

D 69% ^{63}Cu and 31% ^{65}Cu

E 36% ^{63}Cu and 64% ^{65}Cu

F 64% ^{63}Cu and 36% ^{65}Cu

Question 4

a) Arsenic oxide As_2O_3 is prepared on an industrial scale by roasting arsenic-containing ores such as arsenopyrite, FeAsS, in air. The other products formed are iron(III) oxide and sulfur dioxide.

b) As_2O_3 is moderately soluble in water; one dm^3 of a saturated solution at 25 °C contains 20.6 g. When dissolved in water, the oxide reacts to form arsenous acid, H_3AsO_3.

(ii) Give an equation for the formation of arsenous acid from As_2O_3 when dissolved in water. **[2 marks]**

Answer: .....

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(iii) Calculate the concentration of the arsenous acid, in mol dm^{-3}, in the saturated solution. **[2 marks]**

Answer: .....

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c) Homeopathic medicines are made by preparing an extremely dilute solution of some compound, such as As_2O_3. Typically a saturated solution is diluted by a factor of 10^{30}.

(i) Assuming that the solution referred to in **(b)** is diluted by a factor of 10^{30}, calculate the mass (in g) of As_2O_3 present in a 100 cm^3 of the diluted solution. **[2 marks]**

Answer: .....

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(ii) Given that 0.1 g of As_2O_3 is usually fatal, calculate the volume (in m^3) of the diluted solution that would be needed for a fatal dose of As_2O_3. Also express your answer as a fraction of the volume of the Earth (approximately 1.08×10^{12} km^3). **[4 marks]**

Answer: .....

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(iii) The diluted solution is usually sold in 'one ounce' bottles (1 ounce = 28 cm^3). Calculate how many bottles of the solution need to be bought in order, on average, to purchase one atom of arsenic. **[4 marks]**

Answer: .....

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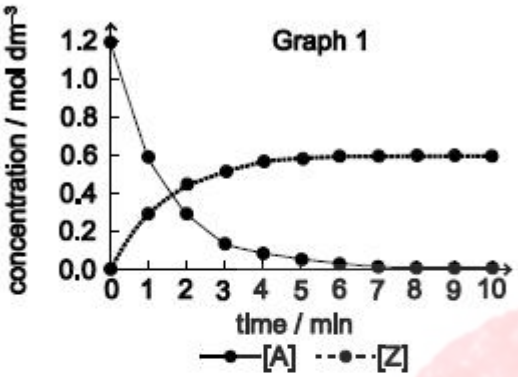
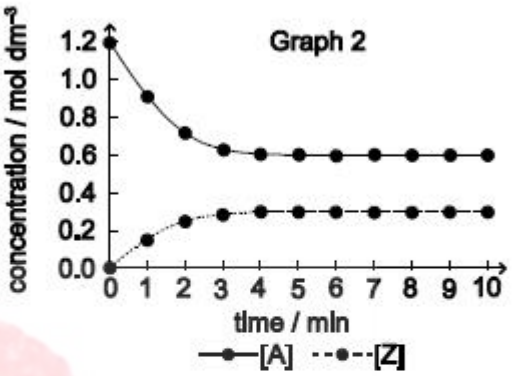
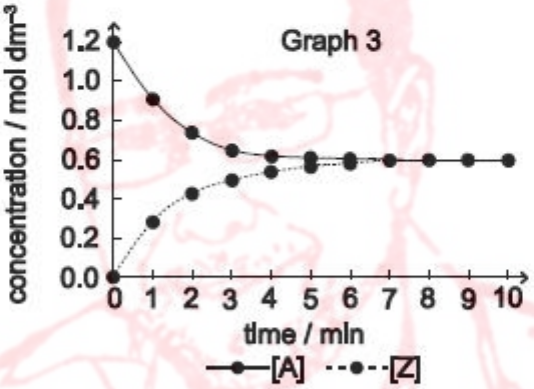
40 Chemicals A and B react to form products Y and Z. The reaction goes to completion. The equation for the reaction is:

$$2A(aq) + B(aq) \rightarrow Y(aq) + Z(aq)$$

Equimolar samples of A and B were mixed and the concentrations of A and Z were measured over time. Which of the following graphs could represent this reaction?







A Graph 1 only

B Graph 2 only

C Graph 3 only

D Graphs 1 and 2 only

E Graphs 2 and 3 only

A Level Topic # **2 Q# 75/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)**

41 An oxide of iron has the formula Fe_3O_4 and contains both Fe^{2+} and Fe^{3+} ions.

Which one of the following is the fraction of iron ions that are in the Fe^{2+} state?

A $\frac{1}{4}$

B $\frac{1}{3}$

C $\frac{1}{2}$

D $\frac{2}{3}$

E $\frac{3}{4}$

A Level Topic # **2 Q# 76/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)**

45 What volume of water vapour measured at room temperature and pressure would be produced from an ice cube of mass 6.00 g if it all evaporated?

(A_r: H = 1; O = 16, molar volume of a gas at room temperature and pressure = 24 dm^3)

A 240 cm^3

B 1800 cm^3

C 4800 cm^3

D 8000 cm^3

E 24 000 cm^3

A Level Topic # **2 Q# 77/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)**

46 A compound of iodine and oxygen contains 63.5 g of iodine and 20.0 g of oxygen.

Which one of the following is its empirical formula?

(A_r: I = 127; O = 16)

A IO

B IO_2

C I_2O

D I_2O_3

E I_2O_5

F I_5O_2

50 Carbon, in the form of coke, is used to reduce iron oxide in a blast furnace. The three stages are shown below:

1 $C + O_2 \rightarrow CO_2$

2 $CO_2 + C \rightarrow 2CO$

3 $3CO + Fe_2O_3 \rightarrow 2Fe + 3CO_2$

If 12 g of carbon is used in stage 2 and all the carbon monoxide produced is used in stage 3, what mass of carbon dioxide is produced in stage 3?

(A_r: C = 12; O = 16)

A 17.8 g

B 35.6 g

C 44 g

D 88 g

E 132 g

52 An impure sample of sodium hydroxide has a mass of 1.20 g. All the sodium hydroxide completely reacts with a minimum of 50.0 cm^3 of 0.50 mol dm^{-3} hydrochloric acid.

What is the percentage purity of the sodium hydroxide sample?

(A_r: H = 1; O = 16; Na = 23; Cl = 35.5)

A 37.5%

B 41.6%

C 72.7%

D 75.0%

E 83.3%

F 90.4%

A Level Topic # **2 Q# 80/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)**

53 A sample of an alkali XOH of mass 2.8 g was dissolved in water.

This solution was neutralised by 12.5 cm^3 of sulfuric acid of concentration 2.0 mol dm^{-3}.

$$2XOH(aq) + H_2SO_4(aq) \rightarrow X_2SO_4(aq) + 2H_2O(l)$$

What is the relative atomic mass of X?

(A_r: H = 1; O = 16; S = 32)

A 13

B 26

C 39

D 52

E 65

F 78

A Level Topic # **2 Q# 81/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)**

54 The equation summarises the reaction of copper and dilute nitric acid.

$$Cu + \boldsymbol{r}HNO_3 \rightarrow Cu(NO_3)_2 + \boldsymbol{s}H_2O + \boldsymbol{t}NO_2$$

What values of ***s*** and ***t*** are needed to balance the equation?

	s	***t***
A	1	1
B	2	1
C	4	1
D	2	2
E	4	2

b) Breakfast cereals frequently have elemental iron added to them as a dietary supplement. A method for making a quantitative measurement of the amount of iron is to use the reaction between $Fe^{3+}(aq)$ and thiocyanate, $SCN^{-}(aq)$, which gives the deep red complex $FeSCN^{2+}(aq)$.

$$Fe^{3+}(aq) + SCN^{-}(aq) \longrightarrow FeSCN^{2+}(aq)$$

The depth of the colour can be measured using a *spectrophotometer* which gives a value for the *absorbance* that is proportional to the concentration of the complex:

$$\text{absorbance} = \text{constant} \times [FeSCN^{2+}] \qquad \textbf{Equation 1}$$

The constant can be found by measuring the absorbance of a solution of known concentration.

(i) The absorbance of a solution of the complex with concentration 2.5×10^{-4} mol dm^{-3} was measured to be 1.85; determine the value of the constant in Equation 1. **[2 marks]**

Answer: .....

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100 g of breakfast cereal was mixed with sufficient dilute acid to dissolve all of the iron. The solution was carefully filtered and mixed with sufficient oxidising agent to convert all of the iron to Fe^{3+}. The solution was made up to a total volume of 250 cm^3. 10.0 cm^3 of this solution was mixed with 10.0 cm^3 of a solution of thiocyanate; you may assume that all of the iron is converted to the complex. The absorbance of the resulting solution was measured as 0.519.

(ii) Using the value of the constant found in **(i)**, calculate the concentration of Fe^{3+} in the solution for which the absorbance was measured. **[2 marks]**

Answer: .....

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(iii) Hence calculate the concentration of Fe^{3+} in the solution prepared from the cereal.

[2 marks]

Answer: .....

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(iv) Hence calculate the mass of iron present in the 100 g of breakfast cereal (A_r: Fe = 55.85).

[4 marks]

Answer: .....

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41 Several oxides of bromine have been identified. Analysis of 2.4 g of one of these compounds showed it to contain 1.6 g of bromine.

What is the empirical formula of this compound?

(A_r: bromine = 80; oxygen = 16)

A Br_2O

B BrO_2

C Br_2O_5

D Br_5O_2

E Br_4O_5

F Br_5O_4

42 The most common ion of antimony, Sb^{3+}, has 48 electrons.

Antimony has two isotopes. One isotope has 70 neutrons and has an abundance of 60%. The second isotope has 72 neutrons and has an abundance of 40%.

What is the relative atomic mass of antimony?

A 70.8

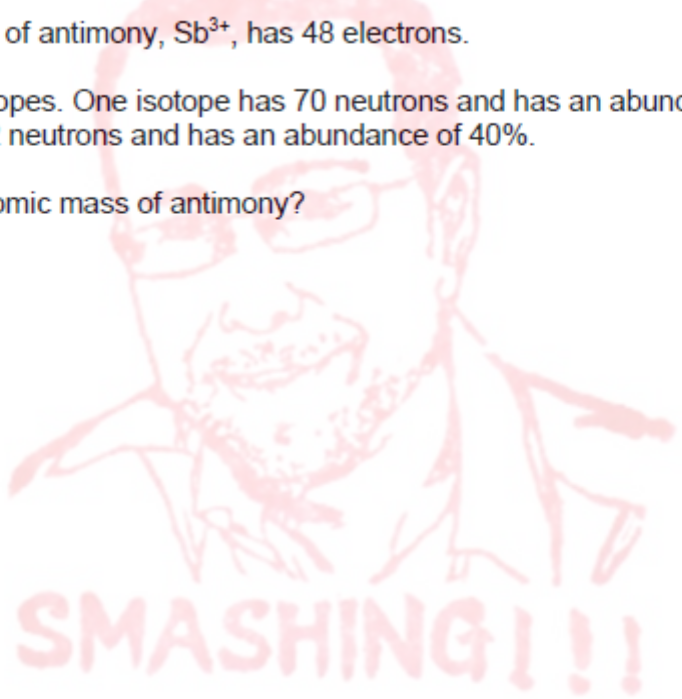
B 71.0

C 71.2

D 121.8

E 122.0

F 122.2



46 Copper, Cu, reacts with concentrated nitric acid, HNO_3, to produce a solution of copper(II) nitrate, water and compound X.

Compound X does not contain copper or hydrogen.

The balanced equation for the reaction shows 3 moles of copper reacting with HNO_3 to produce 4 moles of water.

What is the identity of compound X?

A NO

B NO_2

C NO_3

D N_2O_5

E N_2O_8

50 A 1.50 g sample of impure anhydrous sodium carbonate was added to 100 cm^3 of excess dilute hydrochloric acid. The impurity is unreactive.

The volume of gas released was 240 cm^3 at room temperature and pressure.

What is the mass of the impurity?

(A_r: Na = 23; C = 12; O = 16; molar gas volume = 24 000 cm^3 at room temperature and pressure)

A 0.44 g

B 0.53 g

C 0.67 g

D 0.83 g

E 0.97 g

F 1.06 g

A Level Topic # **2 Q# 87/ Cambridge/2016/Section 1 www.SmashingScience.org**

51 0.35 g of lithium metal reacts with excess water at room temperature. Any gas produced in the reaction is collected and its volume measured at room temperature and pressure.

Assuming 1 mole of gas occupies 24.0 dm^3 at room temperature and pressure, what is the volume of gas collected?

(A_r: Li = 7)

A 0.00 cm^3

B 0.60 cm^3

C 1.20 cm^3

D 25.0 cm^3

E 50.0 cm^3

F 600 cm^3

G 1200 cm^3

A Level Topic # **2 Q# 88/ Cambridge/2016/Section 1 www.SmashingScience.org**

52 Sodium sulfate was prepared by neutralising 25.0 cm^3 of 0.1 mol dm^{-3} sodium hydroxide with exactly 50.0 cm^3 of sulfuric acid.

What is the concentration of the sulfuric acid in g dm^{-3}?

(M_r: H_2SO_4 = 98)

A 0.025 g dm^{-3}

B 0.050 g dm^{-3}

C 0.250 g dm^{-3}

D 2.45 g dm^{-3}

E 4.90 g dm^{-3}

F 9.80 g dm^{-3}

A Level Topic # **2 Q# 89/**
A Level Topic # **2 Q# 90/**
A Level Topic # **2 Q# 91/**

19 Bromine trifluoride, BrF_3, is a simple molecular compound containing single bonds only.

It is **not** trigonal planar.

Two of the bond lengths in this molecule are 0.181 nm, and the third is 0.172 nm.

The through-space distances between two fluorine atoms are 0.241 nm or 0.361 nm.

What is the acute bond angle in BrF_3?

A $\sin^{-1}\left(\frac{0.1205}{0.172}\right)$

B $\cos^{-1}\left(\frac{0.1205}{0.172}\right)$

C $\sin^{-1}\left(\frac{0.1205}{0.181}\right)$

D $\cos^{-1}\left(\frac{0.1205}{0.181}\right)$

E $\sin^{-1}\left(\frac{0.172}{0.1805}\right)$

F $\cos^{-1}\left(\frac{0.172}{0.1805}\right)$

G $\sin^{-1}\left(\frac{0.1805}{0.181}\right)$

H $\cos^{-1}\left(\frac{0.1805}{0.181}\right)$

43 Consider the following properties of compound X:

melting point	–114 °C
boiling point	–85 °C
conductivity as a solid	poor
conductivity as a liquid	poor
conductivity in aqueous solution	good

Which one of the following could be the identity of compound X?

A ammonium chloride, NH_4Cl

B barium chloride, $BaCl_2$

C hydrogen chloride, HCl

D potassium chloride, KCl

E tetrachloromethane, CCl_4

50 Element Z is in Group 1 of the Periodic Table.

A pure sample of element Z consists of two isotopes with mass numbers 85 and 87, and has a relative atomic mass of 85.5.

Which of the following statements is/are correct about element Z in this sample?

1 Element Z reacts with bromine to form an ionic compound with formula ZBr_2.

2 Element Z forms a basic oxide.

3 More than 70% of the atoms of element Z have mass number 85.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

43 Consider the following properties of compound X:

melting point	–114 °C
boiling point	–85 °C
conductivity as a solid	poor
conductivity as a liquid	poor
conductivity in aqueous solution	good

Which one of the following could be the identity of compound X?

A ammonium chloride, NH_4Cl

B barium chloride, $BaCl_2$

C hydrogen chloride, HCl

D potassium chloride, KCl

E tetrachloromethane, CCl_4

22 Which of the following statements is correct for the bond angle (θ) in gaseous germanium(II) chloride, $GeCl_2$, molecules as predicted by the VSEPR model?

A $\theta = 90°$

B $90° < \theta < 120°$

C $\theta = 120°$

D $120° < \theta < 180°$

E $\theta = 180°$

31 A compound contains potassium cations, and anions that contain only boron and fluorine. Each anion contains one boron atom.

0.630 g of this compound contains 0.195 g of potassium and 0.055 g of boron.

What is the shape of the anions in this compound?

(A_r values: B = 11; F = 19; K = 39)

A linear

B bent (V-shaped)

C trigonal planar

D trigonal pyramidal

E tetrahedral

F square planar

19 Bromine trifluoride, BrF_3, is a simple molecular compound containing single bonds only.

It is **not** trigonal planar.

Two of the bond lengths in this molecule are 0.181 nm, and the third is 0.172 nm.

The through-space distances between two fluorine atoms are 0.241 nm or 0.361 nm.

What is the acute bond angle in BrF_3?

A $\sin^{-1}\left(\frac{0.1205}{0.172}\right)$

B $\cos^{-1}\left(\frac{0.1205}{0.172}\right)$

C $\sin^{-1}\left(\frac{0.1205}{0.181}\right)$

D $\cos^{-1}\left(\frac{0.1205}{0.181}\right)$

E $\sin^{-1}\left(\frac{0.172}{0.1805}\right)$

F $\cos^{-1}\left(\frac{0.172}{0.1805}\right)$

G $\sin^{-1}\left(\frac{0.1805}{0.181}\right)$

H $\cos^{-1}\left(\frac{0.1805}{0.181}\right)$

A Level Topic # **3 Q# 99/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org**

43 Which substance (**A**-**E**) in the table could have a giant covalent structure?

substance	*melting point* / °C	*boiling point* / °C	*electrical conductivity*	
			when solid	*when molten*
A	1700	2200	none	none
B	800	1470	none	good
C	98	880	good	good
D	–20	58	none	none
E	–39	357	good	good

A Level Topic # **3 Q# 100/ Cambridge/2019/Section 1 www.SmashingScience.org**

38 In which of the following solids does the bonding consist of single covalent bonds **only**?

1 graphite

2 SiO_2

3 Al_2O_3

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

A Level Topic # **3 Q# 101/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)**

39 Which substance (A–E) in the table could have a giant covalent structure?

substance	*melting point* / °C	*boiling point* / °C	*electrical conductivity*	
			when solid	*when molten*
A	1700	2200	none	none
B	800	1470	none	good
C	98	880	good	good
D	–20	58	none	none
E	–39	357	good	good

Question 3

Parts **a)**, **b)** and **c)** can be answered independently of one another.

a) Draw two alternative 'dot and cross' diagrams to describe the bonding in the linear thiocyanate anion SCN^-. In one diagram place the negative charge on the sulfur, and in the other place the negative charge on the nitrogen. **[5 marks]**

Answer:

52 A typical sample of dry air is at room temperature and pressure. There is a total of 25.0 mol of gas in this sample.

One of the gases in the sample, X, contributes 1.50×10^{23} separate particles to the mixture.

A second gas in the sample, Y, would, if alone, occupy a volume of 468 dm^3 at room temperature and pressure.

What are the identities of gases X and Y, and what would be the total amount of all of the remaining gases in the sample?

(Take Avogadro's number as 6.00×10^{23}. Assume that one mole of any gas occupies a volume of 24.0 dm^3 at room temperature and pressure.)

	identity of gas X	*identity of gas Y*	*total amount of all of the remaining gases in the sample in moles*
A	Ar	N_2	5.250 mol
B	O_2	N_2	5.250 mol
C	O_2	Ar	5.250 mol
D	Ar	O_2	5.375 mol
E	Ar	N_2	5.375 mol
F	O_2	N_2	5.375 mol

60 Airbags in cars contain sodium azide (NaN_3) as a primary reagent, and potassium nitrate (KNO_3) as a secondary reagent.

The sodium azide decomposes according to the following equation to form nitrogen gas, which rapidly fills the airbag:

$$2NaN_3 \rightarrow 2Na + 3N_2$$

The sodium by-product of this first reaction then reacts with excess potassium nitrate according to this second equation:

$$10Na + 2KNO_3 \rightarrow K_2O + 5Na_2O + N_2$$

Assume that both reactions go to completion.

An airbag contains 130 g of sodium azide.

What is the total volume of nitrogen gas formed in this airbag, measured at room temperature and pressure?

(A_r values: N = 14.0; Na = 23.0. Assume that one mole of gas occupies 24.0 dm^3 at room temperature and pressure.)

A 72.0 dm^3

B 76.8 dm^3

C 84.0 dm^3

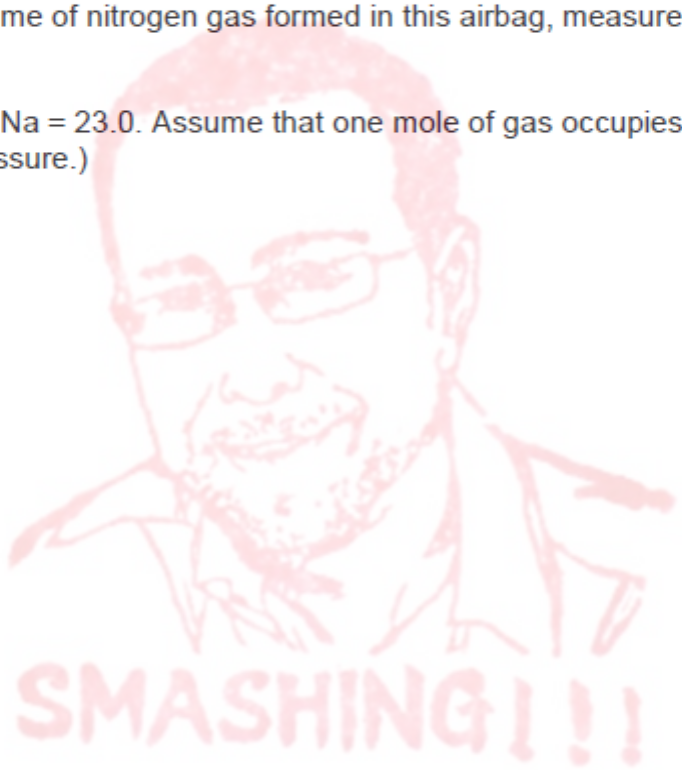
D 89.6 dm^3

E 96.0 dm^3

F 112 dm^3

G 120 dm^3

H 140 dm^3



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	identity of gas X	*identity of gas Y*	*total amount of all of the remaining gases in the sample in moles*
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B	O_2	N_2	5.250 mol
C	O_2	Ar	5.250 mol
D	Ar	O_2	5.375 mol
E	Ar	N_2	5.375 mol
F	O_2	N_2	5.375 mol

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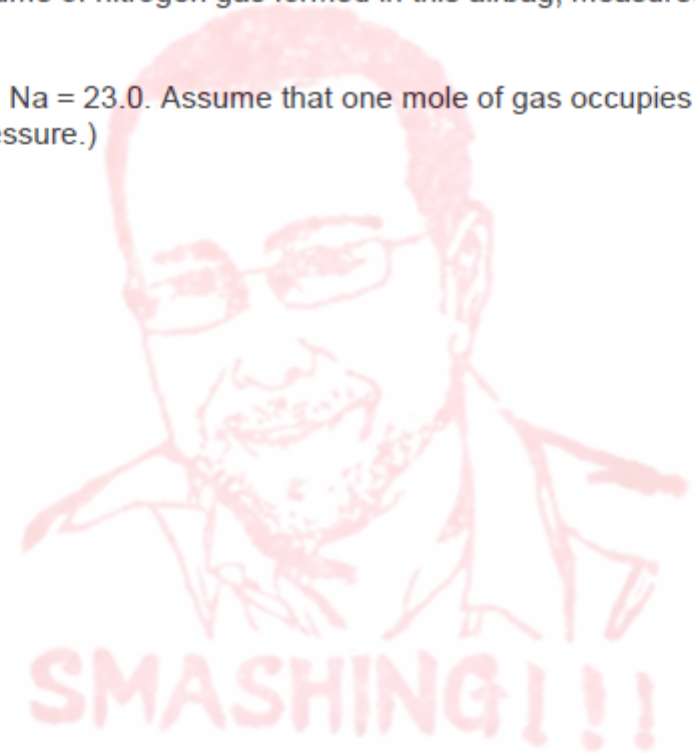

56 The balanced equation for an oxidation of ammonia is:

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

50.0 dm^3 of ammonia and 50.0 dm^3 of oxygen, both at 850 °C and 1 atmosphere pressure, are mixed and allowed to react to form the products shown in the equation. No other reactions occur.

What is the maximum total volume of gases (at 850 °C and 1 atmosphere pressure) after the reaction?

(Assume that all gases have the same volume at the given temperature and pressure.)

A 100 dm^3

B 110 dm^3

C 111 dm^3

D 125 dm^3

E 200 dm^3

53 A mixture of equal parts of hexane (bp 68 °C) and heptane (bp 98 °C) is distilled using a fractionating column.

The temperature of the liquid in the flask and the temperature at the top of the fractionating column are measured.

Which one of the following shows the likely temperatures when the first drops of distillate are collected?

	temperature in flask / °C	*temperature at top of column / °C*
A	83	68
B	98	68
C	83	83
D	98	83
E	98	98

41 Use the following data table to answer the question.

gas	*melting point* / °C	*boiling point* / °C
hydrogen	–259	–253
nitrogen	–210	–196
oxygen	–219	–183
neon	–249	–246
argon	–189	–186

Water and carbon dioxide were removed from a sample of air and the remaining mixture was cooled to –260 °C.

The three most abundant remaining elements are to be separated by fractional distillation.

In which order would these three elements be collected?

A hydrogen, neon, nitrogen

B hydrogen, neon, oxygen

C neon, nitrogen, argon

D neon, nitrogen, oxygen

E nitrogen, argon, oxygen

F nitrogen, oxygen, argon

G oxygen, nitrogen, argon

H oxygen, argon, nitrogen

51 100 cm^3 of ethane is mixed with 1400 cm^3 of oxygen and the mixture is ignited.

All volumes are measured at atmospheric pressure and a temperature of 150 °C.

What will be the **total** volume of gas after the complete combustion?

(Assume that equal amounts of any gas at the same temperature and pressure occupy the same volume.)

A 500 cm^3

B 1250 cm^3

C 1500 cm^3

D 1550 cm^3

E 1700 cm^3

F 2000 cm^3

41 Use the following data table to answer the question.

gas	*melting point* / °C	*boiling point* / °C
hydrogen	–259	–253
nitrogen	–210	–196
oxygen	–219	–183
neon	–249	–246
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B hydrogen, neon, oxygen

C neon, nitrogen, argon

D neon, nitrogen, oxygen

E nitrogen, argon, oxygen

F nitrogen, oxygen, argon

G oxygen, nitrogen, argon

H oxygen, argon, nitrogen

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What will be the **total** volume of gas after the complete combustion?

(Assume that equal amounts of any gas at the same temperature and pressure occupy the same volume.)

A 500 cm^3

B 1250 cm^3

C 1500 cm^3

D 1550 cm^3

E 1700 cm^3

F 2000 cm^3

50 A technician needs to separate three liquids (X, Y and Z) which have been accidentally mixed together. None of the liquids react with each other.

liquid	X	Y	Z
boiling point / °C	65	51	100
density / g cm^{-3}	0.79	0.68	1.00

X and Z are miscible, but Y is immiscible with both X and Z.

The technician uses a separating funnel to separate the upper and lower layers of the mixture.

What should the technician do next to maximise separation of the three liquids?

A distil the lower layer at 51 °C

B distil the lower layer at 65 °C

C distil the lower layer at 100 °C

D distil the upper layer at 51 °C

E distil the upper layer at 65 °C

F distil the upper layer at 100 °C

41 The gases nitrogen, oxygen and argon can be separated from liquefied air by fractional distillation.

Given the data in the table, in which order would the gases be collected?

	melting point / °C	*boiling point* / °C
nitrogen	–210	–196
oxygen	–218	–183
argon	–189	–186

A nitrogen, oxygen, argon

B nitrogen, argon, oxygen

C oxygen, nitrogen, argon

D oxygen, argon, nitrogen

E argon, nitrogen, oxygen

F argon, oxygen, nitrogen

Question 4

a) Arsenic oxide As_2O_3 is prepared on an industrial scale by roasting arsenic-containing ores such as arsenopyrite, FeAsS, in air. The other products formed are iron(III) oxide and sulfur dioxide.

b) As_2O_3 is moderately soluble in water; one dm^3 of a saturated solution at 25 °C contains 20.6 g. When dissolved in water, the oxide reacts to form arsenous acid, H_3AsO_3.

(i) Given that other measurements show all the hydrogen atoms in H_3AsO_3 to be in the same environment, suggest a structure for the acid. What is the geometry around the arsenic atom? **[2 marks]**

Answer: .....

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49 A mixture of equal parts of hexane (bp 68 °C) and heptane (bp 98 °C) is distilled using a fractionating column.

The temperature of the liquid in the flask and the temperature at the top of the fractionating column are measured.

Which one of the following shows the likely temperatures when the first drops of distillate are collected?

	temperature in flask / °C	*temperature at top of column / °C*
A	83	68
B	98	68
C	83	83
D	98	83
E	98	98

A Level Topic # 5 **Q# 119/ Cambridge/2022sp/Section 2/ www.SmashingScience.org**

11 A methane gas burner heats objects with only 20% efficiency.

The gas burner is used to heat a 500 g copper pan containing 400 g water from 20 °C to 80 °C.

specific heat capacities: copper = 0.4 J g^{-1} $°C^{-1}$; water = 4 J g^{-1} $°C^{-1}$

standard enthalpy change of combustion of methane = −900 kJ mol^{-1}

What is the minimum mass of methane gas required?

(M_r value: methane = 16)

A 1.92 g

B 2.40 g

C 8.53 g

D 9.60 g

E 11.4 g

F 12.8 g

G 21.12 g

12 Mercury(II) fulminate, $HgC_2N_2O_2$, can decompose to produce carbon monoxide and two different elements only.

The enthalpy change for the decomposition of one mole of mercury(II) fulminate is –606 kJ.

The enthalpy change of formation for mercury(II) fulminate is +386 kJ mol^{-1}.

What is the enthalpy change of formation of carbon monoxide?

(Assume that all data is given at the same temperature and pressure.)

A –110 kJ mol^{-1}

B +110 kJ mol^{-1}

C –166 kJ mol^{-1}

D +166 kJ mol^{-1}

E –220 kJ mol^{-1}

F +220 kJ mol^{-1}

G –496 kJ mol^{-1}

H +496 kJ mol^{-1}

16 The following information should be used in calculating the answer to this question:

- Standard enthalpy change of formation of ethanol:

  $\Delta_f H°(CH_3CH_2OH(l)) = -277\,kJ\,mol^{-1}$

- Standard enthalpy change of vaporisation of ethanol, $CH_3CH_2OH(l) \rightarrow CH_3CH_2OH(g)$:

  $\Delta_{vap} H°(CH_3CH_2OH(l)) = +39\,kJ\,mol^{-1}$

- Standard enthalpy change of atomisation of carbon, $C(s) \rightarrow C(g)$:

  $\Delta_{at} H°(C(s)) = +715\,kJ\,mol^{-1}$

The table provides some average bond enthalpy data:

bond	C–C	C–O	H–H	O–H	O=O
average bond enthalpy / kJ mol^{-1}	346	358	436	463	498

Using the data provided, which of the following is the average bond enthalpy of the C–H bond?

A 342 kJ mol^{-1}

B 412 kJ mol^{-1}

C 417 kJ mol^{-1}

D 419 kJ mol^{-1}

E 461 kJ mol^{-1}

F 481 kJ mol^{-1}

G 483 kJ mol^{-1}

H 673 kJ mol^{-1}

57 A student mixed together 30.0 cm^3 of 3.0 mol dm^{-3} hydrochloric acid and 20.0 cm^3 of 4.0 mol dm^{-3} aqueous ammonia in an insulated container.

The initial temperatures of both solutions were 20.0 °C.

The maximum temperature observed was 40.0 °C.

Assume that the specific heat capacity of any aqueous solution is 4.0 J g^{-1} $°C^{-1}$ and that the density of the reaction mixture is 1.0 g cm^{-3}.

Using this information, what is the molar enthalpy change, in kJ mol^{-1}, for the reaction of hydrochloric acid and aqueous ammonia?

A –4 kJ mol^{-1}

B –20 kJ mol^{-1}

C –25 kJ mol^{-1}

D –30 kJ mol^{-1}

E –44 kJ mol^{-1}

F –50 kJ mol^{-1}

G –75 kJ mol^{-1}

H –100 kJ mol^{-1}

57 A student mixed together 30.0 cm^3 of 3.0 mol dm^{-3} hydrochloric acid and 20.0 cm^3 of 4.0 mol dm^{-3} aqueous ammonia in an insulated container.

The initial temperatures of both solutions were 20.0 °C.

The maximum temperature observed was 40.0 °C.

Assume that the specific heat capacity of any aqueous solution is 4.0 J g^{-1} $°C^{-1}$ and that the density of the reaction mixture is 1.0 g cm^{-3}.

Using this information, what is the molar enthalpy change, in kJ mol^{-1}, for the reaction of hydrochloric acid and aqueous ammonia?

A –4 kJ mol^{-1}

B –20 kJ mol^{-1}

C –25 kJ mol^{-1}

D –30 kJ mol^{-1}

E –44 kJ mol^{-1}

F –50 kJ mol^{-1}

G –75 kJ mol^{-1}

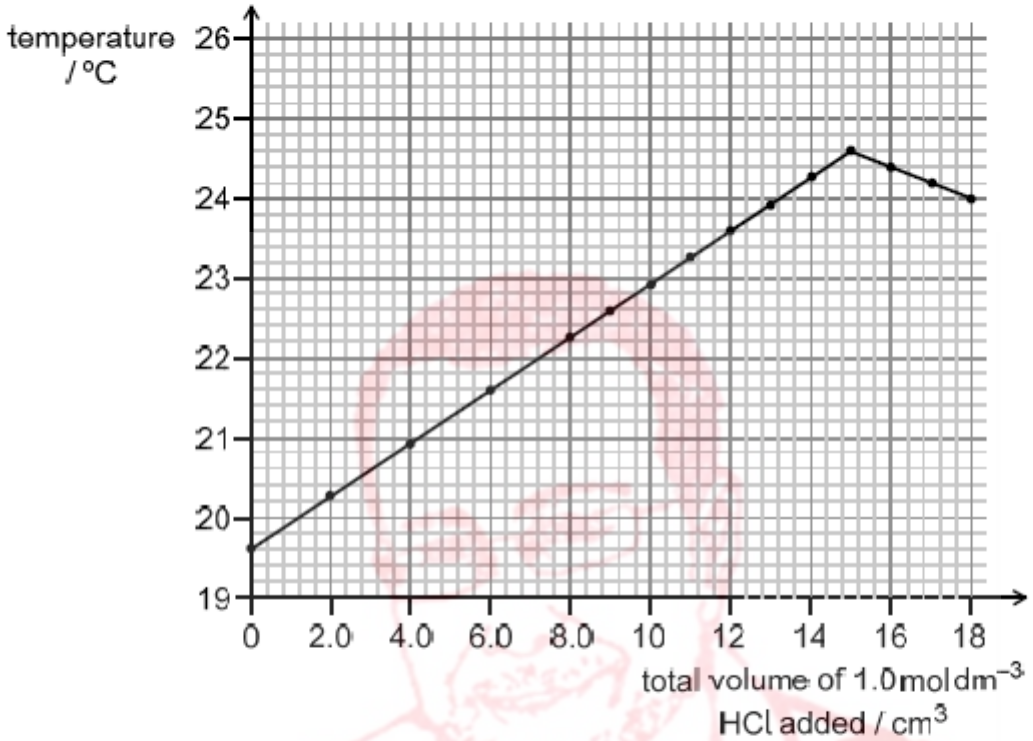
H –100 kJ mol^{-1}

27 25.0 cm^3 of sodium hydroxide solution is placed in a polystyrene cup with a thermometer.

1.00 mol dm^{-3} hydrochloric acid is added from a burette to the stirred solution of sodium hydroxide.

Both solutions are at the same temperature before mixing.

The temperature is recorded each time a measured amount of hydrochloric acid is added, and the data is plotted on a graph.



Assuming that no heat is lost from the cup, what is the enthalpy change of reaction when one mole of aqueous sodium hydroxide is neutralised?

(Assume that all solutions have density 1.0 g cm^{-3} and specific heat capacity 4.2 J g^{-1} $°C^{-1}$.)

A –56.0 kJ

B –49.3 kJ

C –35.0 kJ

D –33.6 kJ

E –21.0 kJ

34 The standard enthalpy change of formation of hydrogen iodide is +26 kJ mol^{-1}.

For the reaction of gaseous iodine with hydrogen

$$I_2(g) + H_2(g) \rightleftharpoons 2HI(g)$$

the enthalpy change of reaction can be calculated using bond enthalpy values.

The bond enthalpies are:

bond	*bond enthalpy* / kJ mol^{-1}
H – H	436
I – I	151
H – I	299

The sublimation of iodine is represented by: $I_2(s) \rightarrow I_2(g)$

Using the data provided, what is the enthalpy change for the sublimation of iodine?

(All data is given at room temperature and pressure.)

A –262 kJ mol^{-1}

B –236 kJ mol^{-1}

C –41 kJ mol^{-1}

D +37 kJ mol^{-1}

E +41 kJ mol^{-1}

F +63 kJ mol^{-1}

G +236 kJ mol^{-1}

54 Propene burns in air. For each mole of propene burned, 2000 kJ of heat is released.

2.10 g of propene is burned to heat a 1000 g sample of olive oil.

The olive oil has an initial temperature of 23.0 °C. It takes 2.00 J to heat one gram of olive oil by 1.0 °C.

Assume that all heat is transferred to the olive oil and none is lost to the surroundings.

What is the maximum temperature reached by the oil?

(M_r value: $C_3H_6 = 42.0$)

A 20.0 °C

B 43.0 °C

C 48.0 °C

D 50.0 °C

E 73.0 °C

F 100 °C

G 200 °C

H 223 °C

55 What is the calculated energy change for the following reaction using appropriate values from the data provided?

$$CH_4(g) + 2H_2O(g) \rightarrow CO_2(g) + 4H_2(g)$$

bond	*bond energy* / kJ mol^{-1}
H – H	440
O – H	460
C – H	430
C – O	360
C=O	800
C≡O	1070

A +200 kJ mol^{-1}

B –200 kJ mol^{-1}

C +720 kJ mol^{-1}

D –720 kJ mol^{-1}

E +1080 kJ mol^{-1}

F –1080 kJ mol^{-1}

11 A methane gas burner heats objects with only 20% efficiency.

The gas burner is used to heat a 500 g copper pan containing 400 g of water from 20 °C to 80 °C.

specific heat capacities: copper = 0.4 J g^{-1} °C^{-1}; water = 4 J g^{-1} °C^{-1}

standard enthalpy change of combustion of methane = –900 kJ mol^{-1}

What is the minimum mass of methane gas required?

(M_r value: methane = 16)

A 1.92 g

B 2.40 g

C 8.53 g

D 9.60 g

E 11.4 g

F 12.8 g

G 21.12 g

12 Mercury(II) fulminate, $HgC_2N_2O_2$, can decompose to produce carbon monoxide and two different elements only.

The enthalpy change for the decomposition of one mole of mercury(II) fulminate is –606 kJ.

The enthalpy change of formation for mercury(II) fulminate is +386 kJ mol^{-1}.

What is the enthalpy change of formation of carbon monoxide?

(Assume that all data is given at the same temperature and pressure.)

A –110 kJ mol^{-1}

B +110 kJ mol^{-1}

C –166 kJ mol^{-1}

D +166 kJ mol^{-1}

E –220 kJ mol^{-1}

F +220 kJ mol^{-1}

G –496 kJ mol^{-1}

H +496 kJ mol^{-1}

47 The reaction between nitrogen and hydrogen to form ammonia is exothermic.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H \text{ is negative}$$

The bond energies in the three molecules are as shown:

N≡N	x kJ mol^{-1}
H–H	y kJ mol^{-1}
N–H	z kJ mol^{-1}

Which statement can be deduced from this information?

A $z > x + y$

B $2z > x + y$

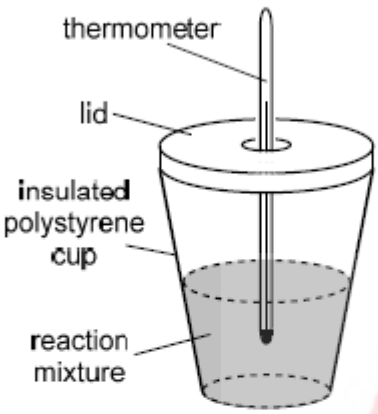
C $2z > x + 3y$

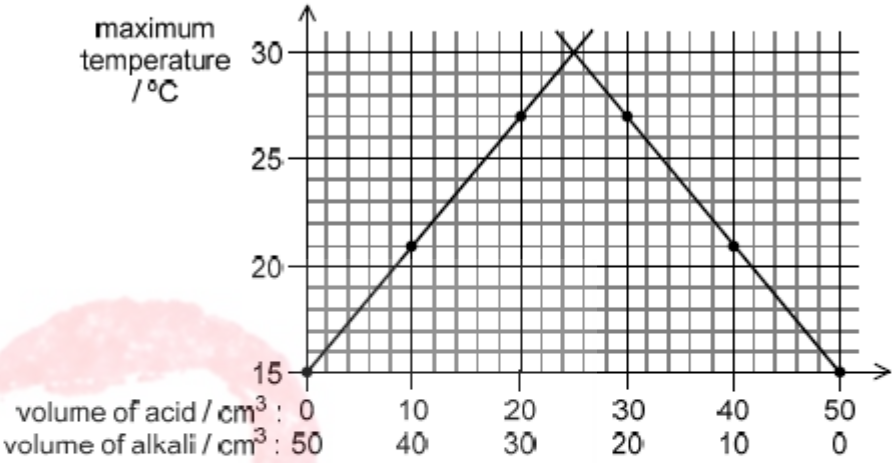
D $6z > x + 3y$

58 Four separate experiments were carried out using different quantities of 2 mol dm^{-3} hydrochloric acid and 2 mol dm^{-3} sodium hydroxide in insulated polystyrene cups.

After stirring, the maximum temperature was recorded and the results plotted on a graph as shown.

The temperatures of the acid and alkali on their own were also plotted on the graph. Two straight lines were drawn and extrapolated as shown.





What is the molar enthalpy change for the neutralisation reaction, in kJ mol^{-1}?

(Assume that the specific heat capacity of the solutions is 4 J g^{-1} °C^{-1}, the density of dilute solutions is 1 g cm^{-3}, and all heat is transferred to the solution.)

A 3 kJ mol^{-1}

B 6 kJ mol^{-1}

C 30 kJ mol^{-1}

D 60 kJ mol^{-1}

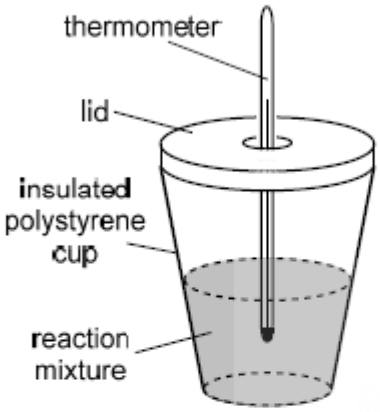
E 120 kJ mol^{-1}

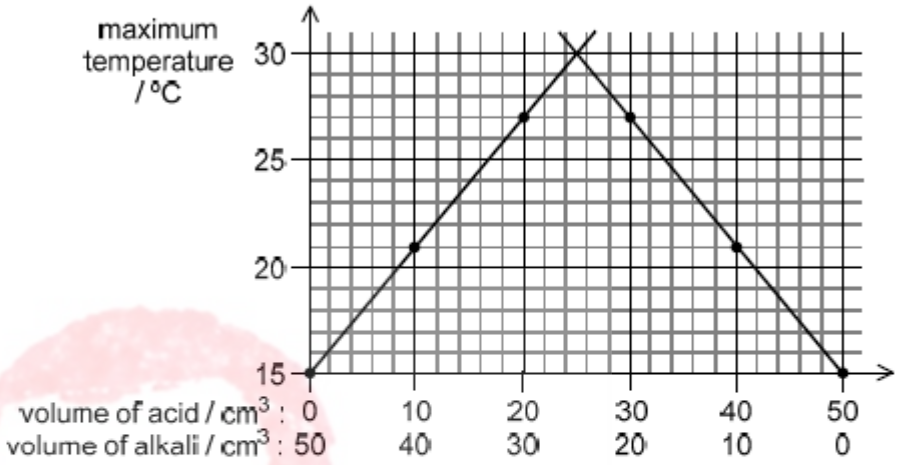
F 3000 kJ mol^{-1}

58 Four separate experiments were carried out using different quantities of 2 mol dm^{-3} hydrochloric acid and 2 mol dm^{-3} sodium hydroxide in insulated polystyrene cups.

After stirring, the maximum temperature was recorded and the results plotted on a graph as shown.

The temperatures of the acid and alkali on their own were also plotted on the graph. Two straight lines were drawn and extrapolated as shown.





What is the molar enthalpy change for the neutralisation reaction, in kJ mol^{-1}?

(Assume that the specific heat capacity of the solutions is 4 J g^{-1} $°C^{-1}$, the density of dilute solutions is 1 g cm^{-3}, and all heat is transferred to the solution.)

A 3 kJ mol^{-1}

B 6 kJ mol^{-1}

C 30 kJ mol^{-1}

D 60 kJ mol^{-1}

E 120 kJ mol^{-1}

F 3000 kJ mol^{-1}

53 The Haber process is represented by the following chemical equation:

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

What is the overall enthalpy change for the reaction?

(Bond enthalpies: $N \equiv N = 945\,kJ\,mol^{-1}$; $H-H = 435\,kJ\,mol^{-1}$; $N-H = 390\,kJ\,mol^{-1}$)

A $+90\,kJ\,mol^{-1}$

B $-90\,kJ\,mol^{-1}$

C $+990\,kJ\,mol^{-1}$

D $-990\,kJ\,mol^{-1}$

E $+1080\,kJ\,mol^{-1}$

F $-1080\,kJ\,mol^{-1}$

49 Nitrogen and hydrogen react together to form ammonia as shown below:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

The energy released by this reaction is $93\,kJ\,mol^{-1}$.

What is the bond energy in the nitrogen molecule?

(Bond energies: $H-H = 436\,kJ\,mol^{-1}$; $N-H = 391\,kJ\,mol^{-1}$)

A $315\,kJ\,mol^{-1}$

B $513\,kJ\,mol^{-1}$

C $644\,kJ\,mol^{-1}$

D $864\,kJ\,mol^{-1}$

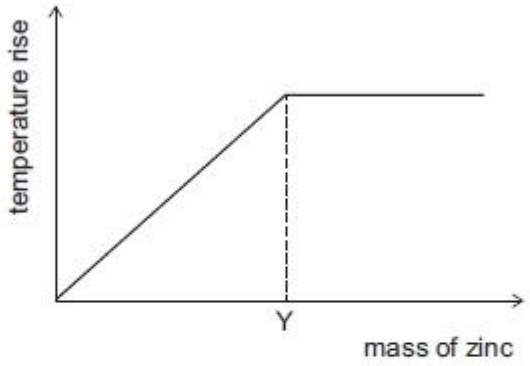
E $945\,kJ\,mol^{-1}$

F $1131\,kJ\,mol^{-1}$

51 Silver nitrate solution reacts with zinc powder in an exothermic reaction:

$$2AgNO_3(aq) + Zn(s) \rightarrow 2Ag(s) + Zn(NO_3)_2(aq)$$

The graph shows the maximum temperature rise as different masses of zinc react with separate 50.0 cm^3 samples of 0.100 mol dm^{-3} silver nitrate solution.



What is the mass of zinc at the position labelled Y?

(A_r value: Zn = 65)

A 0.163 g

B 0.325 g

C 0.650 g

D 1.63 g

E 3.25 g

F 6.50 g

d) The table below gives values of the standard enthalpies of combustion, $\Delta_c H^\circ$, of **A**, **B**, carbon (as graphite) and hydrogen.

	A	***B***	*C(s) (graphite)*	$H_2(g)$
$\Delta_c H^\circ$ / kJ mol^{-1}	−2058	−2091	−393.5	−241.8

(i) Give the balanced chemical equation for the complete combustion of C_3H_6. **[2 marks]**

Answer: .....

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(ii) Calculate the standard enthalpy of formation, $\Delta_f H^\circ$, of A. **[3 marks]**

Answer: .....

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(iii) Calculate the standard enthalpy of formation of **B**. **[3 marks]**

Answer: .....

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(iv) Calculate the standard enthalpy change for the reaction **B** → **A**. Comment on the value you obtain. **[2 marks]**

Answer: .....

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e) The standard enthalpy of combustion of C_6H_{12} is $-3920\,kJ\,mol^{-1}$. Using this value and the corresponding value for **B**, calculate the average contribution $\Delta_c H^\circ$ per CH_2 group for the two compounds. Comment on your result. **[4 marks]**

Answer: .....

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43 The reaction between nitrogen and hydrogen to form ammonia is exothermic.

$$N_2(g) + 3H_2(g) \leftrightharpoons 2NH_3(g) \quad \Delta H \text{ is negative}$$

The bond energies in the three molecules are as shown.

N ≡ N	x kJ mol^{-1}
H – H	y kJ mol^{-1}
N – H	z kJ mol^{-1}

Which statement can be deduced from this information?

A $z > x + y$

B $2z > x + y$

C $2z > x + 3y$

D $6z > x + y$

E $6z > x + 3y$

A Level Topic # **5 Q# 138/ Cambridge/2016/Section 2/ www.SmashingScience.org**

Samples of the six alkenes, in a random order, are labelled **P**, **Q**, **R**, **S**, **T**, and **U**. You will be able to identify which isomer *some* of these correspond to using the information and data throughout the rest of the question.

Alkenes **P**, **Q**, and **R** react with hydrogen gas and a metal catalyst to give the same alkane **A**; alkenes **S**, **T**, and **U** react under the same conditions to give a different alkane **B**.

Both alkanes **A** and **B** react with chlorine gas under UV light to form chloroalkanes with the formula $C_5H_{11}Cl$. Under such conditions, alkane **A** forms *four* different structural isomers, whereas **B** gives *three*.

f) Use the data to calculate the standard enthalpy change of combustion of alkene **P**.

[4 marks]

Answer: .....

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A Level Topic # **5 Q# 139/ Cambridge/2016/Section 1 www.SmashingScience.org**

48 The heat energy change for a reaction is $-100\,kJ\,mol^{-1}$, and the activation energy is $+150\,kJ\,mol^{-1}$.

What is the activation energy for the reverse reaction?

A $-250\ kJ\ mol^{-1}$

B $-150\ kJ\ mol^{-1}$

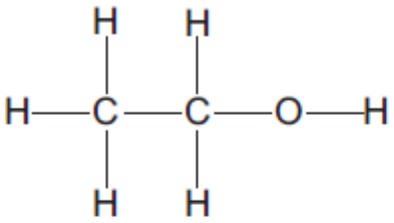
C $-50\ kJ\ mol^{-1}$

D $+50\ kJ\ mol^{-1}$

E $+150\ kJ\ mol^{-1}$

F $+250\ kJ\ mol^{-1}$

54 The structure of ethanol is given below:



Given the equation below and the overall enthalpy change for the reaction, which option correctly identifies the bond energy of the C–O bond in ethanol?

$$H_2C{=}CH_2(g) + H_2O(g) \rightarrow C_2H_5OH(g) \qquad \Delta H = -45\,kJ\,mol^{-1}$$

(Mean bond energy ($kJ\,mol^{-1}$): H–H = +436; C–C = +346; C–H = +413; O–H = +464; C=C = +611)

A $103\,kJ\,mol^{-1}$

B $316\,kJ\,mol^{-1}$

C $361\,kJ\,mol^{-1}$

D $707\,kJ\,mol^{-1}$

E $825\,kJ\,mol^{-1}$

A Level Topic # 6 **Q# 141/ Cambridge/2022/Section 2/ www.SmashingScience.org**

45 Which of the following chemical reactions is/are redox reactions?

1 $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

2 $PCl_5(s) + H_2O(l) \rightarrow POCl_3(l) + 2HCl(aq)$

3 $KrF_2(s) \rightarrow Kr(g) + F_2(g)$

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

45 Which of the following chemical reactions is/are redox reactions?

1 $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

2 $PCl_5(s) + H_2O(l) \rightarrow POCl_3(l) + 2HCl(aq)$

3 $KrF_2(s) \rightarrow Kr(g) + F_2(g)$

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

48 Some students were trying to assign oxidation numbers to each of the four sulfur atoms in the tetrathionate ion, $S_4O_6^{2-}$.

Which of the following lists gives the possible oxidation states of the four sulfur atoms present?

A 0, 0, +6, +6

B +3, +3, +3, +3

C 0, +2, +6, +6

D 0, 0, +5, +5

E –2, –2, +7, +7

A Level Topic # **6 Q# 144/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org**

48 In which two of the following equations is the **first reactant** an oxidising agent?

1 **Mg** + 2HCl → $MgCl_2$ + H_2

2 **$Cr_2O_7^{2-}$** + $6Fe^{2+}$ + $14H^+$ → $2Cr^{3+}$ + $6Fe^{3+}$ + $7H_2O$

3 **$2Cu^{2+}$** + $4I^-$ → 2CuI + I_2

4 **H_2SO_3** + $2Fe^{3+}$ + H_2O → H_2SO_4 + $2Fe^{2+}$ + $2H^+$

A 1 and 2

B 1 and 4

C 2 and 3

D 2 and 4

E 3 and 4

A Level Topic # **6 Q# 145/ Cambridge/2020/Section 2/ www.SmashingScience.org**

50 Which of the following equations represent(s) a redox reaction?

1 $K_2Cr_2O_7$ + 2KOH → $2K_2CrO_4$ + H_2O

2 $8HNO_3$ + $3C_2H_6O$ + $K_2Cr_2O_7$ → $2KNO_3$ + $3C_2H_4O$ + $7H_2O$ + $2Cr(NO_3)_3$

3 H_2O + SO_2 → H_2SO_3

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

50 Which of the following equations represent(s) a redox reaction?

1 $K_2Cr_2O_7 + 2KOH \rightarrow 2K_2CrO_4 + H_2O$

2 $8HNO_3 + 3C_2H_6O + K_2Cr_2O_7 \rightarrow 2KNO_3 + 3C_2H_4O + 7H_2O + 2Cr(NO_3)_3$

3 $H_2O + SO_2 \rightarrow H_2SO_3$

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

44 Which of the following chemical equations represent(s) a redox reaction?

1 $2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$

2 $Al^{3+} + 3e^- \rightarrow Al$

3 $2Ag^+ + 2OH^- \rightarrow Ag_2O + H_2O$

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

43 The following equations show the main reactions that take place in a blast furnace during the extraction of iron and the removal of the impurities:

$$C + O_2 \rightarrow CO_2$$

$$\underline{CO_2} + C \rightarrow 2CO$$

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

$$\underline{CaCO_3} \rightarrow CaO + CO_2$$

$$\underline{CaO} + SiO_2 \rightarrow CaSiO_3$$

Which row in the following table correctly identifies whether the underlined substance is oxidised, or reduced, or neither?

	CO_2	$CaCO_3$	CaO
A	oxidised	reduced	neither
B	oxidised	neither	neither
C	oxidised	reduced	oxidised
D	oxidised	neither	oxidised
E	reduced	reduced	neither
F	reduced	neither	neither
G	reduced	reduced	oxidised
H	reduced	neither	oxidised

43 Solid copper(II) chloride contains Cu^{2+} ions and Cl^- ions only.

Solid lithium phosphate(V) contains Li^+ ions and PO_4^{3-} ions only.

Aqueous solutions of copper(II) chloride and lithium phosphate(V) are mixed to produce a precipitate of copper(II) phosphate(V) and an aqueous solution of lithium chloride.

Which of the following represents the balanced ionic equation for this process?

A $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

B $2Cu^{2+}(aq) + 3PO_4^{3-}(aq) \rightarrow Cu_2(PO_4)_3(s)$

C $2Cu^{2+}(aq) + 5PO_4^{3-}(aq) \rightarrow Cu_2(PO_4)_5(s)$

D $3Cu^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Cu_3(PO_4)_2(s)$

E $3Cu^{2+}(aq) + 6Cl^-(aq) + 6Li^+(aq) + 2PO_4^{3-}(aq) \rightarrow Cu_3(PO_4)_2(s) + 6LiCl(aq)$

F $3CuCl_2(aq) + 2Li_3PO_4(aq) \rightarrow Cu_3(PO_4)_2(s) + 6LiCl(aq)$

A Level Topic # **6 Q# 150/ Cambridge/2017/Section 1 www.SmashingScience.org**

44 Which of the following statements about the reaction of lithium with water are correct?

1 The reaction is a redox reaction.

2 7 g of lithium will react with excess water to produce 2 g of hydrogen gas.

3 The reaction produces a solution with a pH greater than that of water.

4 14 g of lithium will exactly react with 36 g of water.

(A_r values: H = 1; Li = 7; O = 16)

A 1 and 2 only

B 1 and 4 only

C 1, 2 and 3 only

D 1, 3 and 4 only

E 2 and 3 only

F 3 and 4 only

A Level Topic # **6 Q# 151/ Cambridge/2016SP/Section 2/ www.SmashingScience.org**

Question 4

a) Arsenic oxide As_2O_3 is prepared on an industrial scale by roasting arsenic-containing ores such as arsenopyrite, FeAsS, in air. The other products formed are iron(III) oxide and sulfur dioxide.

(i) What is the oxidation state of the arsenic in As_2O_3? **[1 mark]**

Answer: .....

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(ii) Give a balanced chemical equation for the industrial production of As_2O_3 from FeAsS. **[2 marks]**

Answer: .....

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44 In which two of the following equations is the **first reactant** an oxidising agent?

1 $\mathbf{Mg} + 2HCl \rightarrow MgCl_2 + H_2$

2 $\mathbf{Cr_2O_7^{2-}} + 6Fe^{2+} + 14H^+ \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$

3 $\mathbf{2Cu^{2+}} + 4I^- \rightarrow 2CuI + I_2$

4 $\mathbf{H_2SO_3} + 2Fe^{3+} + H_2O \rightarrow H_2SO_4 + 2Fe^{2+} + 2H^+$

A 1 and 2

B 1 and 4

C 2 and 3

D 2 and 4

E 3 and 4

c) Hydrogen peroxide, H_2O_2, is used as the oxidising agent to convert Fe^{2+} to Fe^{3+} in the assay described in **b)(ii)**.

(i) Determine the oxidation state of oxygen in H_2O_2. **[2 marks]**

Answer: .....

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(ii) When H_2O_2 acts as an oxidising agent in acidic solution, what is the oxygen-containing species that is produced and what is the oxidation state of oxygen in this species?

[4 marks]

Answer: .....

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(iii) Write a balanced chemical equation describing the oxidation of $Fe^{2+}(aq)$ to $Fe^{3+}(aq)$ by H_2O_2 in acidic solution. **[4 marks]**

Answer: .....

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A Level Topic # **6 Q# 154/ Cambridge/2016/Section 1 www.SmashingScience.org**

45 Two of the following equations represent redox reactions:

1 $Cl_2 + 2KI \rightarrow I_2 + 2KCl$

2 $Cl_2 + 2e^- \rightarrow 2Cl^-$

3 $HCl + AgNO_3 \rightarrow AgCl + HNO_3$

4 $Cl_2 + H_2O \rightarrow HCl + HClO$

Which two equations represent redox reactions?

A 1 and 2

B 1 and 3

C 1 and 4

D 2 and 3

E 2 and 4

F 3 and 4

56 A sample of magnesium carbonate, $MgCO_3$, was reacted completely with 50 cm^3 of 0.10 mol dm^{-3} hydrochloric acid, which is an excess.

The remaining hydrochloric acid was titrated with 0.20 mol dm^{-3} sodium hydroxide solution. 5.0 cm^3 of sodium hydroxide was required for complete neutralisation.

What was the original mass of magnesium carbonate used, in mg?

(M_r value: $MgCO_3$ = 84)

A 42 mg

B 84 mg

C 168 mg

D 210 mg

E 336 mg

F 420 mg

A Level Topic # **7 Q# 156/ Cambridge/2022/Section 1 www.SmashingScience.org**

48 50 cm^3 of 0.100 mol dm^{-3} hydrochloric acid has a pH of 1.0.

What is the pH of the mixture formed when 450 cm^3 of 0.010 mol dm^{-3} calcium hydroxide solution is added?

A pH = 1.0

B 1.0 < pH < 2.0

C pH = 2.0

D 2.0 < pH < 7.0

E pH = 7.0

F pH > 7.0

56 A sample of magnesium carbonate, $MgCO_3$, was reacted completely with 50 cm^3 of 0.10 mol dm^{-3} hydrochloric acid, which is an excess.

The remaining hydrochloric acid was titrated with 0.20 mol dm^{-3} sodium hydroxide solution. 5.0 cm^3 of sodium hydroxide was required for complete neutralisation.

What was the original mass of magnesium carbonate used, in mg?

(M_r value: $MgCO_3$ = 84)

A 42 mg

B 84 mg

C 168 mg

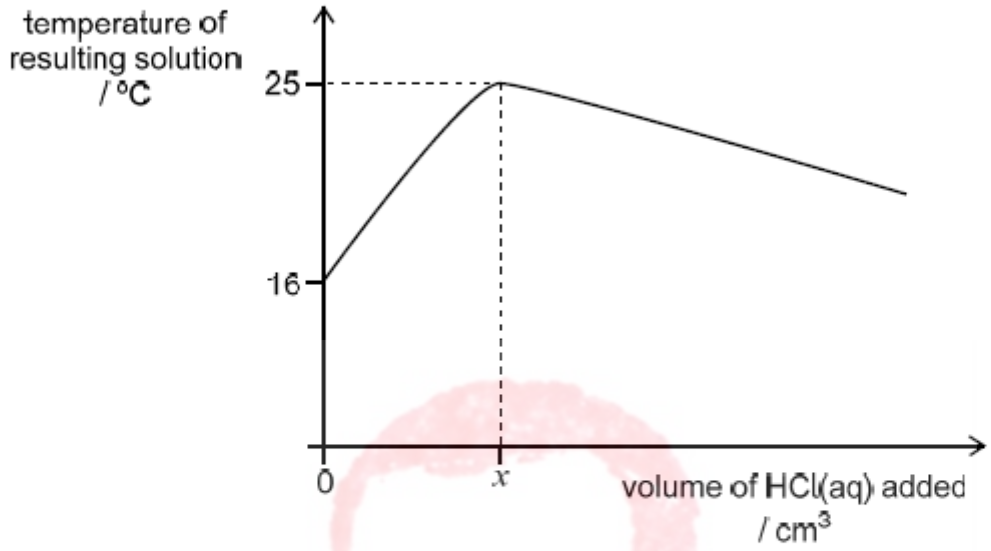
D 210 mg

E 336 mg

F 420 mg

45 1.0 mol dm^{-3} hydrochloric acid was slowly added from a burette into an insulated flask containing 50 cm^3 of aqueous sodium hydroxide. The flask was gently swirled and the temperature of the resulting solution measured continuously.

The two solutions had the same initial temperature and a graph was drawn of the temperature of the resulting solution against the volume of hydrochloric acid added.



Which of the following statements explains the shape of the graph?

A The reaction has reached a state of equilibrium.

B An endothermic reaction occurs after x cm^3 of hydrochloric acid is added.

C The reaction rate decreases as the acid is used up.

D The sodium hydroxide has been neutralised by x cm^3 hydrochloric acid.

E The sodium hydroxide becomes a weaker base as the volume of the resulting solution increases.

53 Ethanedioic acid, $(COOH)_2$, is a weak diprotic acid.

What is the minimum volume of a 2.50 mol dm^{-3} solution of ethanedioic acid required to neutralise 25.0 cm^3 of 2.00 mol dm^{-3} sodium hydroxide solution?

A 10.0 cm^3

B 12.5 cm^3

C 20.0 cm^3

D 25.0 cm^3

E 100 cm^3

16 Deuterium, D, is an isotope of hydrogen. It has one neutron and one proton in its nucleus ($^{2}_{1}H$ is an alternative representation).

Like the more common isotope of hydrogen, $^{1}_{1}H$, deuterium reacts with oxygen to form water.

Consider the following information about hydrogen, deuterium and water:

	bond energy / kJ mol^{-1}
H–H	436
D–D	443
O–H	464
O–D	471

	boiling point / °C
H_2	–252.8
D_2	–249.7
H_2O	100.0
D_2O	101.4

Both H_2O and D_2O dissociate into ions, according to the following equations:

$$H_2O \rightleftharpoons H^+ + OH^- \qquad D_2O \rightleftharpoons D^+ + OD^-$$

At a given temperature, the equilibrium constant for H_2O dissociation is greater than that for D_2O dissociation.

Under the same conditions, which of the following comparisons is/are correct?

1 The reaction of D_2 with oxygen releases less energy than H_2 with oxygen.

2 H_2O is more acidic than D_2O when measured at the same temperature.

3 The boiling points of D_2 and D_2O are higher than H_2 and H_2O, respectively, because the individual bond energies are higher.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

20 Ethanoic acid, ethanol and water were added to a reaction vessel and a quantity of concentrated sulfuric acid was added. The reaction mixture was then heated and an ester (ethyl ethanoate) and water were formed in equilibrium with the reactants.

$$C_2H_5OH(l) + CH_3COOH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$$

120 g of ethanoic acid and 92 g of ethanol were used and the mass of water present at the start of the experiment was 18 g. Assume that there is no change in volume.

At the temperature of the reaction, the equilibrium constant K_c is 2.00.

What is the mass of the ester present in the mixture at equilibrium?

(M_r values: ethanoic acid = 60; ethanol = 46; water = 18; ethyl ethanoate = 88)

A 1.00 g

B 53.0 g

C 88.0 g

D 103 g

E 106 g

F 176 g

G 209 g

H 215 g

41 The colours of three indicators are shown.

indicator	*colour at* *low pH*	*high pH*	*pH at which colour change takes place*
methyl orange	red	yellow	4.0
bromothymol blue	yellow	blue	6.5
phenolphthalein	colourless	pink	9.0

Equal volumes of these three indicators were mixed and the mixture was added to a solution of pH 5.0.

What colour would be seen?

A blue

B green

C orange

D purple

E yellow

55 The following exothermic, reversible reaction is used in the manufacture of sulfuric acid from sulfur dioxide and oxygen:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Which one of the following statements about this reaction is correct?

A Pressure has no effect on the position of equilibrium.

B Raising the temperature moves the equilibrium to the right.

C At equilibrium no sulfur dioxide is being changed into sulfur trioxide.

D The addition of a catalyst speeds up the forward reaction more than the backward reaction.

E Before equilibrium is reached, the rate of the forward reaction is greater than the rate of the backward reaction.

54 Hydrochloric acid, sulfuric acid and phosphoric(V) acid are inorganic acids.

Phosphoric(V) acid, H_3PO_4, ionises in water in the following series of reactions:

$$H_3PO_4 \rightleftharpoons H^+ + H_2PO_4^-$$

$$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$$

$$HPO_4^{2-} \rightleftharpoons H^+ + PO_4^{3-}$$

$0.1\,mol\,dm^{-3}$ hydrochloric acid has a pH of 1.0 at room temperature.

Which of the following statements about these acids is/are correct?

1 The pH of $0.1\,mol\,dm^{-3}$ sulfuric acid is greater than 1.0 at room temperature.

2 $H_2PO_4^-$ can act as an acid or as a base.

3 $30\,cm^3$ of calcium hydroxide solution exactly neutralises $20\,cm^3$ phosphoric(V) acid solution when both solutions are the same concentration.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

60 X is a solution of sulfuric acid.

20.0 cm^3 of X is diluted by adding distilled water to produce 500 cm^3 of solution Y.

10.0 cm^3 of Y is exactly neutralised by 40.0 cm^3 of 0.0500 mol dm^{-3} aqueous potassium hydroxide.

What is the concentration of sulfuric acid in X?

A 0.00100 mol dm^{-3}

B 0.100 mol dm^{-3}

C 0.200 mol dm^{-3}

D 0.400 mol dm^{-3}

E 1.25 mol dm^{-3}

F 2.50 mol dm^{-3}

G 5.00 mol dm^{-3}

H 10.0 mol dm^{-3}

38 The following exothermic reaction reaches equilibrium at room temperature.

$$C_2H_5OH(l) + CH_3COOH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$$

Which of the following changes, when applied independently, will alter the position of the equilibrium?

1 increasing the temperature by 25 °C

2 adding 20 cm^3 of water to the equilibrium mixture

3 adding a catalyst

4 adding an extra 0.5 mol of ethanol (C_2H_5OH)

A 1 only

B 1 and 3 only

C 1, 2 and 4 only

D 2 and 4 only

E 1, 2, 3 and 4

45 In the Contact process, sulfur dioxide reacts with oxygen to make sulfur trioxide in a reversible reaction.

$$SO_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons SO_3(g)$$

When 5.00 mol of SO_2 and 11.0 mol of O_2 are allowed to reach equilibrium at 450 °C, 80.0% of the SO_2 is converted to SO_3.

What is the volume of the resulting mixture?

(Assume that temperature and pressure are constant, and that at this temperature the volume of one mole of gas is 60.0 dm^3.)

A 240 dm^3

B 336 dm^3

C 600 dm^3

D 720 dm^3

E 840 dm^3

F 960 dm^3

54 The following reaction between nitrogen oxide and oxygen releases 116 kJ of energy as heat for each mole of oxygen that reacts.

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

An excess of NO and y moles of oxygen are mixed in a sealed container. The reaction reaches equilibrium in one hour.

At equilibrium, there are z moles of NO_2.

Assume that the pressure is constant throughout the experiment.

How much heat will be released over this hour?

A 0 kJ

B $58y$ kJ

C $116y$ kJ

D $232y$ kJ

E $58z$ kJ

F $116z$ kJ

G $232z$ kJ

A Level Topic # **7 Q# 169/ Cambridge/2017/Section 1 www.SmashingScience.org**

38 Which two of the following reactions involve oxidation?

1 $Ca \rightarrow Ca^{2+} + 2e^-$

2 $Cl_2 + 2e^- \rightarrow 2Cl^-$

3 $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

4 $MgCO_3 + 2HCl \rightarrow MgCl_2 + CO_2 + H_2O$

A 1 and 2 only

B 1 and 3 only

C 1 and 4 only

D 2 and 3 only

E 2 and 4 only

F 3 and 4 only

A Level Topic # **7 Q# 170/ Cambridge/2017/Section 1 www.SmashingScience.org**

39 Hydrochloric acid (HCl) is a strong acid. Properties of a solution of 1.00 mol dm^{-3} hydrochloric acid include:

1 It turns blue litmus indicator red.

2 On reaction with sodium carbonate gaseous carbon dioxide is evolved.

3 25.0 cm^3 of this acid solution neutralises 25.0 cm^3 of 1.00 mol dm^{-3} sodium hydroxide solution.

Ethanoic acid (CH_3COOH) is a weak acid.

Which of the three properties is/are also correct for a 1.00 mol dm^{-3} solution of ethanoic acid?

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

40 Consider the following reactions:

Reaction Q: $CH_2{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g)$ ΔH is −ve

Reaction R: $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ ΔH is +ve

The following actions could be applied independently to each reaction (Q and R) above:

1 increase the pressure

2 increase the temperature

3 use a suitable catalyst

Assuming that all other conditions remain constant, which of these actions will increase the initial rate of reaction **and** increase the yield of products for **both** reactions Q and R?

A none of them

B 1 only

C 1 or 2 only

D 1 or 3 only

E 2 only

F 2 or 3 only

G 3 only

H 1, 2 or 3

37 The colours of three indicators are shown.

indicator	*colour at* *low pH*	*high pH*	*pH at which colour change takes place*
methyl orange	red	yellow	4.0
bromothymol blue	yellow	blue	6.5
phenolphthalein	colourless	pink	9.0

Equal volumes of these three indicators were mixed and the mixture was added to a solution of pH 5.0.

What colour would be seen?

A blue

B green

C orange

D purple

E yellow

A Level Topic # **7 Q# 173/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)**

51 The following exothermic, reversible reaction is used in the manufacture of sulfuric acid from sulfur dioxide and oxygen:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Which one of the following statements about this reaction is correct?

A Pressure has no effect on the position of equilibrium.

B Raising the temperature moves the equilibrium to the right.

C At equilibrium no sulfur dioxide is being changed into sulfur trioxide.

D The addition of a catalyst speeds up the forward reaction more than the backward reaction.

E Before equilibrium is reached, the rate of the forward reaction is greater than the rate of the backward reaction.

A Level Topic # **7 Q# 174/ Cambridge/2016/Section 1 www.SmashingScience.org**

40 In a reversible reaction, gaseous reactants P and Q form gaseous products R and S.

An increase in temperature was found to increase both the rate of reaction and the yield at equilibrium.

An increase in pressure was found to increase the rate of reaction but the yield at equilibrium was unaffected.

Which equation could represent the reaction?

A $3P + Q \rightleftharpoons 2R + 3S$ ΔH is +ve

B $P + 3Q \rightleftharpoons R + 2S$ ΔH is +ve

C $P + 2Q \rightleftharpoons 2R + S$ ΔH is +ve

D $P + 2Q \rightleftharpoons 3R + S$ ΔH is –ve

E $P + 2Q \rightleftharpoons R + S$ ΔH is –ve

F $2P + Q \rightleftharpoons R + 2S$ ΔH is –ve

49 The following tests were carried out on separate samples of two monoprotic acids, HX and HY. HX is a strong acid and HY is a weak acid. Both acids had a concentration of 1 mol dm^{-3}.

1 Measure the time taken for a 1 cm strip of magnesium to react completely when added to 25 cm^3 of each acid.

2 Measure the volume of 1 mol dm^{-3} sodium hydroxide solution needed to completely neutralise 20 cm^3 of each acid.

3 Measure the electrical conductance of each acid using a conductivity meter.

Each test was carried out under the same conditions.

Which of the tests, considered independently, if any, would show that HX was a stronger acid than HY?

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

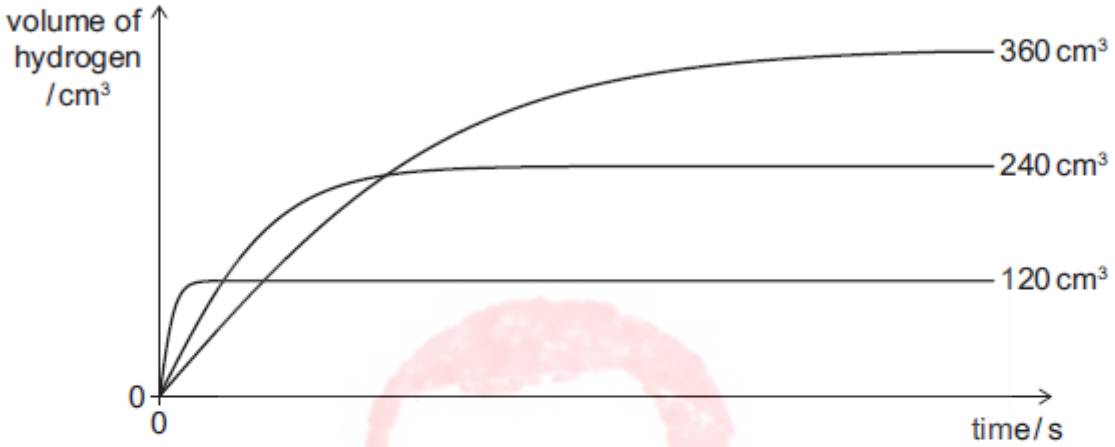
G 2 and 3 only

H 1, 2 and 3

46 Three samples of calcium of different masses were added separately to excess dilute hydrochloric acid and the volume of gas released, measured at room temperature and pressure, was monitored.

One sample was powdered calcium, one was granules of calcium, and one was a solid piece of calcium.

The results are shown on the graph.



What is the mass of powdered calcium used in this experiment?

(A_r value: Ca = 40. Assume that one mole of gas occupies a volume of 24 dm^3 at room temperature and pressure.)

A 0.200 g

B 0.400 g

C 0.600 g

D 1.20 g

E 8.00 g

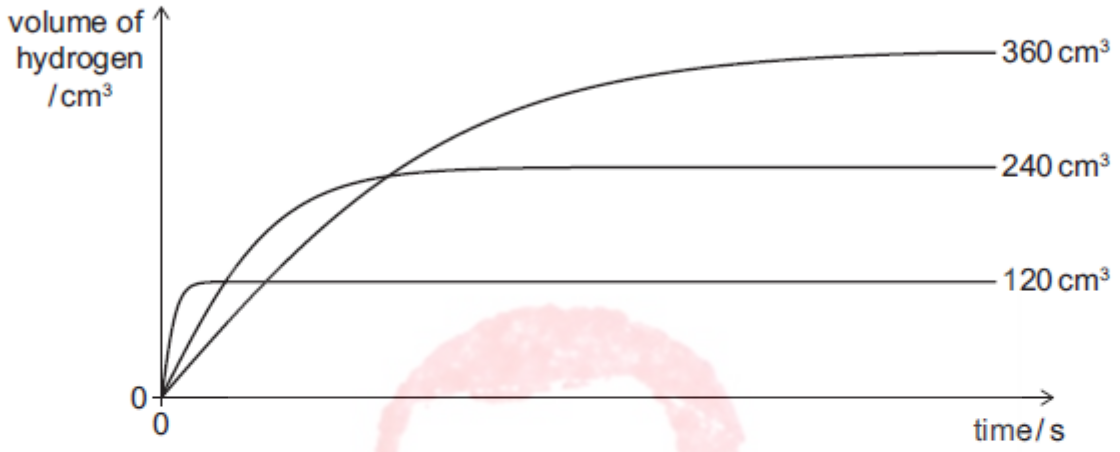
F 16.0 g

G 24.0 g

46 Three samples of calcium of different masses were added separately to excess dilute hydrochloric acid and the volume of gas released, measured at room temperature and pressure, was monitored.

One sample was powdered calcium, one was granules of calcium, and one was a solid piece of calcium.

The results are shown on the graph.



What is the mass of powdered calcium used in this experiment?

(A_r value: Ca = 40. Assume that one mole of gas occupies a volume of 24 dm^3 at room temperature and pressure.)

A 0.200 g

B 0.400 g

C 0.600 g

D 1.20 g

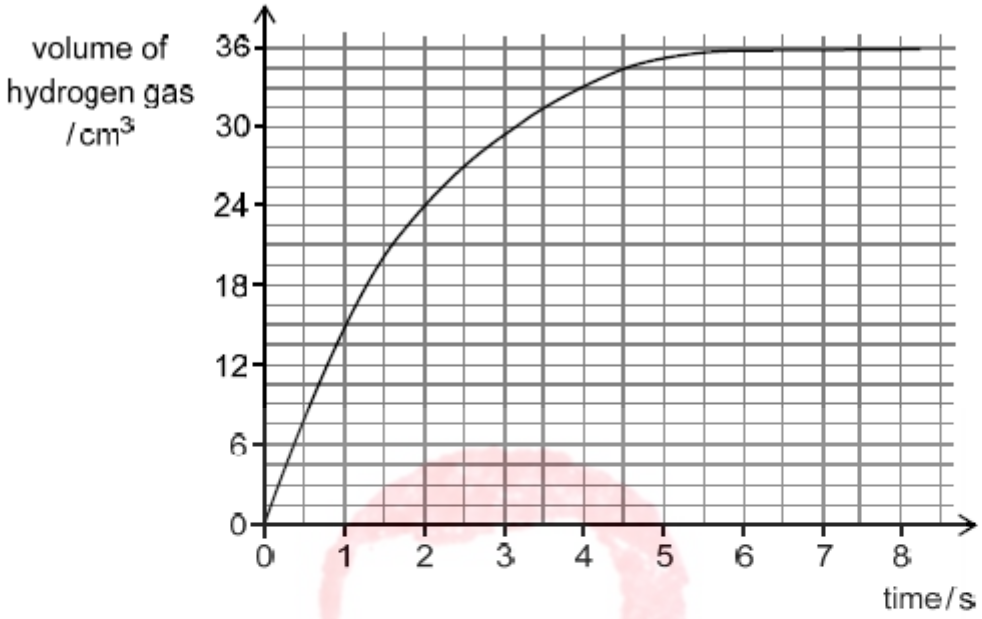
E 8.00 g

F 16.0 g

G 24.0 g

58 0.500 g of magnesium (an excess) was added to dilute hydrochloric acid.

The following graph shows the total volume of the gas released over time as the reaction progresses. All volumes were measured in cm^3 at room temperature and pressure.



What is the mass of magnesium remaining after two seconds?

(A_r value: Mg = 24. Assume that the volume of one mole of gas at room temperature and pressure is 24.0 dm^3.)

A 0.024 g

B 0.036 g

C 0.048 g

D 0.452 g

E 0.464 g

F 0.476 g

60 A spoonful of magnesium carbonate powder was added to excess hydrochloric acid in an open conical flask on an electronic balance.

$$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + CO_2(g) + H_2O(l)$$

The mass of the flask and its contents was measured initially and at 1-minute intervals. The total mass of gas produced was then calculated.

The reaction stopped at 5 minutes.

Which row in the following table could represent the total mass of gas calculated after each measurement?

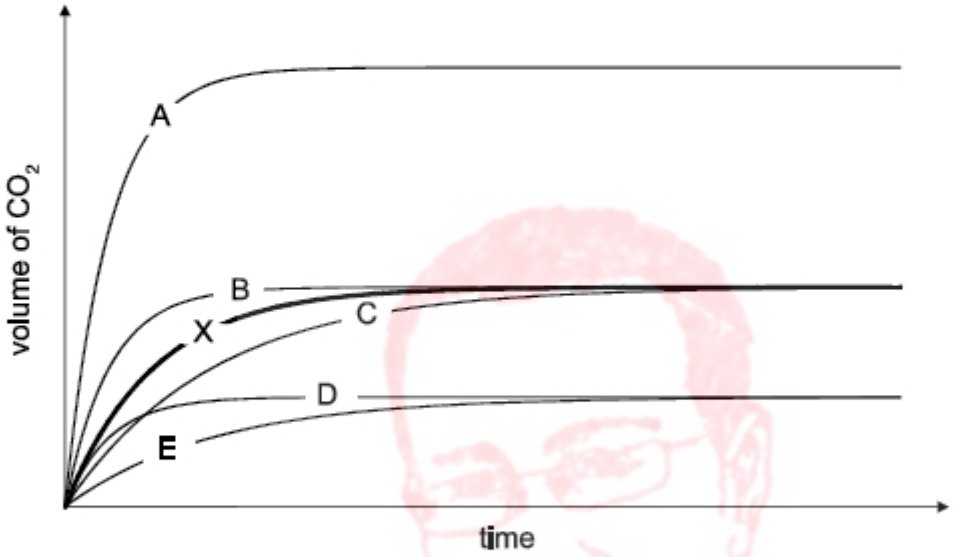
	1 minute	*2 minutes*	*3 minutes*	*4 minutes*	*5 minutes*
A	5 g	9 g	12 g	14 g	15 g
B	1 g	3 g	6 g	10 g	15 g
C	3 g	6 g	9 g	12 g	15 g
D	11 g	12 g	13 g	14 g	15 g
E	6 g	10 g	13 g	15 g	15 g

60 Calcium carbonate reacts with hydrochloric acid. The reaction gives off carbon dioxide gas.

Line **X** on the graph shows the volume of carbon dioxide formed against time when 100 cm^3 of 1.0 mol dm^{-3} of hydrochloric acid reacts with calcium carbonate chips at 20 °C. There was an excess of calcium carbonate chips.

$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O(l)$

Which line best represents the volume of carbon dioxide formed against time when the reaction is repeated with 50 cm^3 of 2.0 mol dm^{-3} of hydrochloric acid reacting with excess calcium carbonate chips at 20 °C?



A line A

B line B

C line C

D line D

E line E

53 Calcium carbonate reacts with hydrochloric acid according to the following chemical equation:

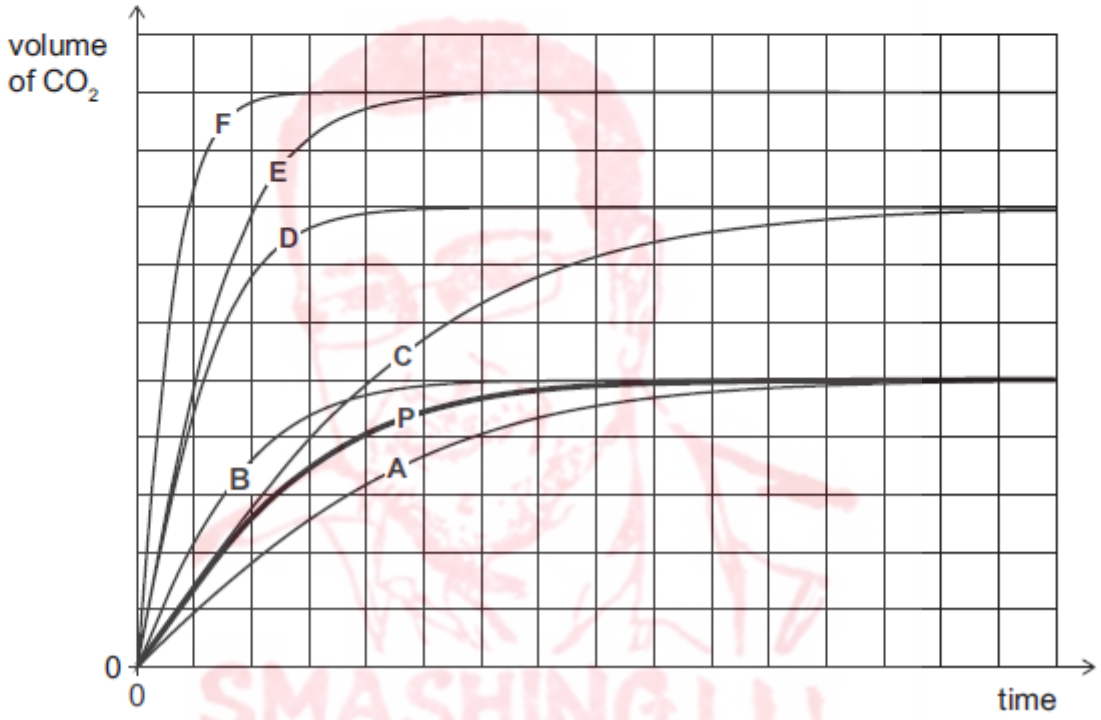
$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

Line **P** on the graph shows how the volume of carbon dioxide formed changes with time when 4.0 g of calcium carbonate reacts with 50 cm^3 of 1.0 mol dm^{-3} hydrochloric acid at 20 °C.

A second reaction was carried out under identical conditions with the same mass of calcium carbonate but using 50 cm^3 of 2.0 mol dm^{-3} hydrochloric acid.

Which line (**A**-**F**) best represents how the volume of carbon dioxide formed changes with time in the second reaction?

(M_r value: $CaCO_3$ = 100)



53 Calcium carbonate reacts with hydrochloric acid according to the following chemical equation:

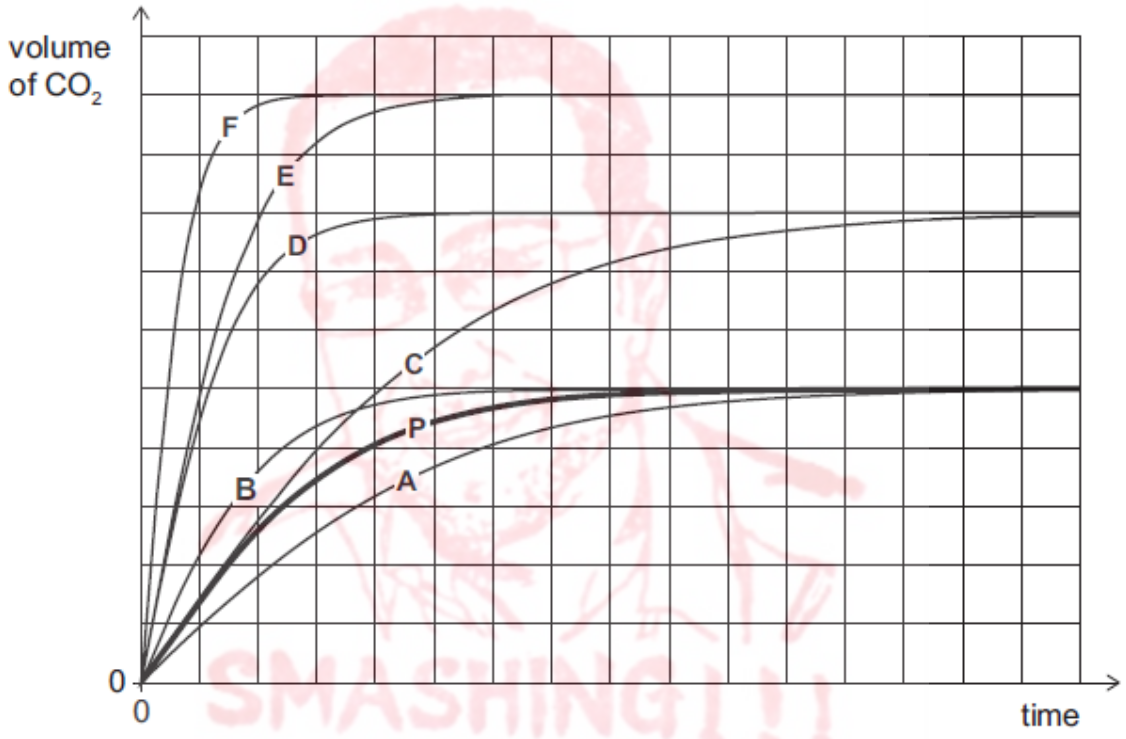
$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

Line **P** on the graph shows how the volume of carbon dioxide formed changes with time when 4.0 g of calcium carbonate reacts with 50 cm^3 of 1.0 mol dm^{-3} hydrochloric acid at 20 °C.

A second reaction was carried out under identical conditions with the same mass of calcium carbonate but using 50 cm^3 of 2.0 mol dm^{-3} hydrochloric acid.

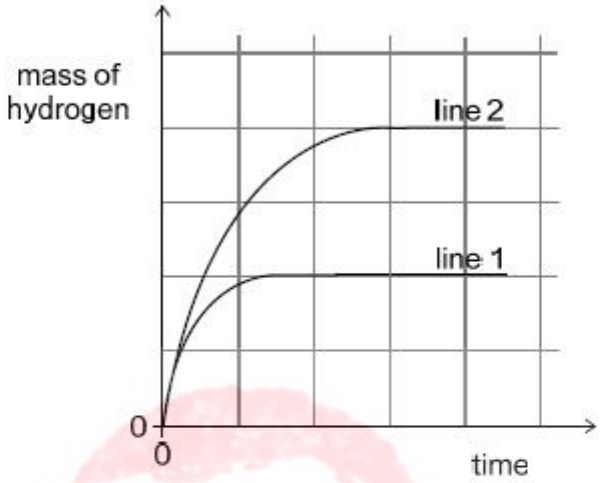
Which line (**A**-**F**) best represents how the volume of carbon dioxide formed changes with time in the second reaction?

(M_r value: $CaCO_3 = 100$)



49 A 2.40 g lump of magnesium was added to 500 cm^3 of a 2.00 mol dm^{-3} solution of HCl in a conical flask that was on an electronic balance. The neck of the flask was plugged with cotton wool, and the decrease in mass of the flask and its contents was recorded at regular intervals.

The mass of the hydrogen released (equal to the mass loss recorded) was plotted against time. The result is line 1 on the graph.



Which of the following experiments performed under the same conditions would give line 2?

(A_r value: Mg = 24.0)

A a 2.40 g lump of magnesium added to 500 cm^3 of 2.00 mol dm^{-3} H_2SO_4

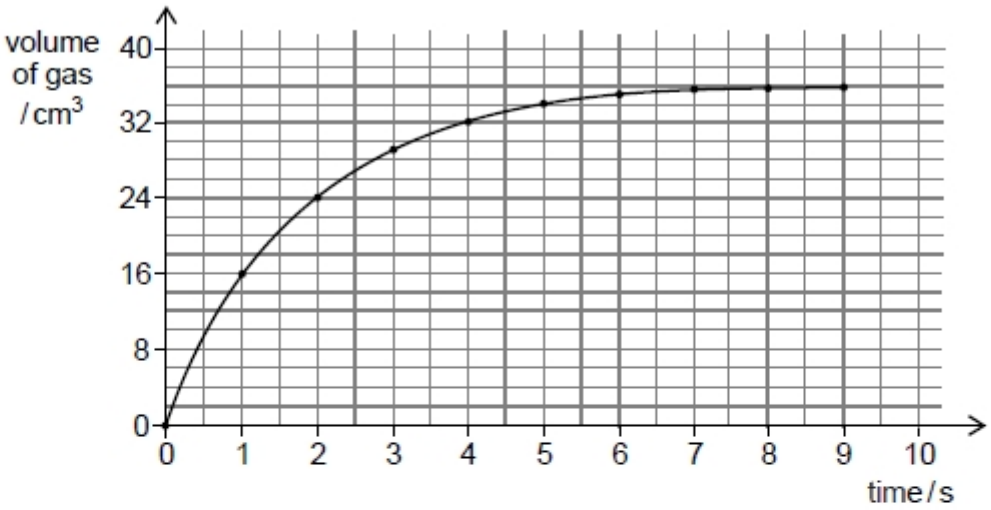
B 2.40 g of magnesium powder added to 500 cm^3 of 2.00 mol dm^{-3} HCl

C a 2.40 g lump of magnesium added to 1000 cm^3 of 2.00 mol dm^{-3} HCl

D a 4.80 g lump of magnesium added to 500 cm^3 of 2.00 mol dm^{-3} HCl

E 4.80 g of magnesium powder added to 500 cm^3 of 2.00 mol dm^{-3} HCl

50 Dilute hydrochloric acid and magnesium were mixed and the total volume of gas released was measured over time.



What is the average rate of reaction, in $g\,s^{-1}$, with respect to the magnesium over the first **two** seconds?

(A_r value: Mg = 24. Assume that the volume of one mole of gas is $24\,dm^3$.)

A $0.012\,g\,s^{-1}$

B $0.024\,g\,s^{-1}$

C $0.048\,g\,s^{-1}$

D $12\,g\,s^{-1}$

E $24\,g\,s^{-1}$

F $48\,g\,s^{-1}$

48 Magnesium reacts with sulfuric acid according to the following chemical equation:

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$$

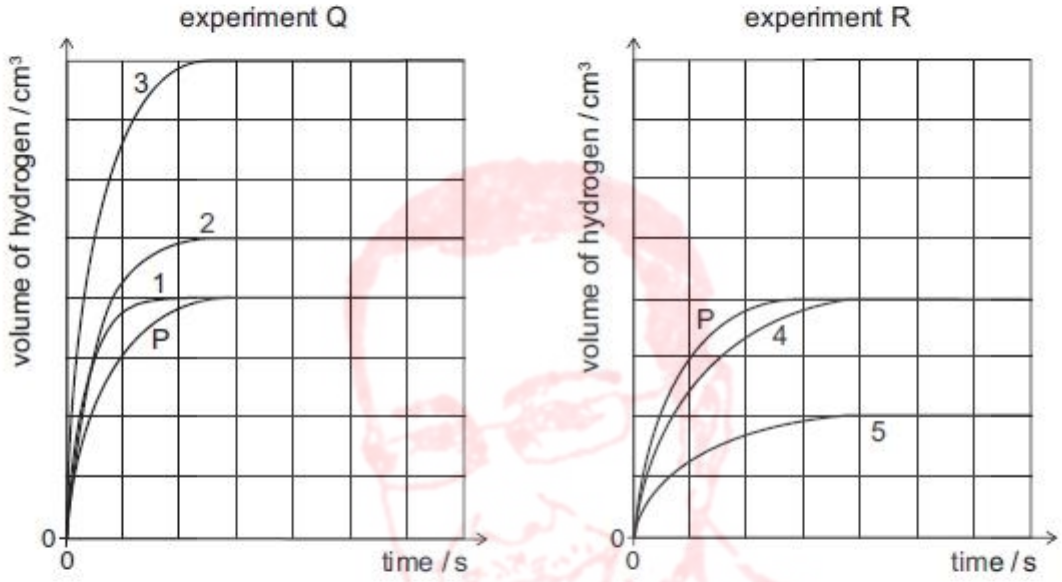
Line P on each graph shows how the volume of hydrogen formed changes with time when 1.2 g of magnesium reacts with 40 cm^3 of 1.0 mol dm^{-3} sulfuric acid at 20 °C.

(A_r value: Mg = 24)

Two further experiments were carried out and the volumes of hydrogen formed were plotted.

Experiment Q: 1.2 g of magnesium + 40 cm^3 of 2.0 mol dm^{-3} sulfuric acid at 20 °C

Experiment R: 1.2 g of magnesium + 40 cm^3 of 0.5 mol dm^{-3} sulfuric acid at 20 °C



Which lines show how the volume of hydrogen formed will change with time in each experiment?

	experiment Q	*experiment R*
A	1	4
B	1	5
C	2	4
D	2	5
E	3	4
F	3	5

53 The reaction between calcium carbonate and hydrochloric acid was used to measure the effect of changing conditions on the mass of CO_2 produced and the rate of CO_2 production.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

The experiment was carried out five times with different conditions at a constant temperature.

The following conditions were varied:

$CaCO_3$ as chips or powder

mass of $CaCO_3$

volume of HCl

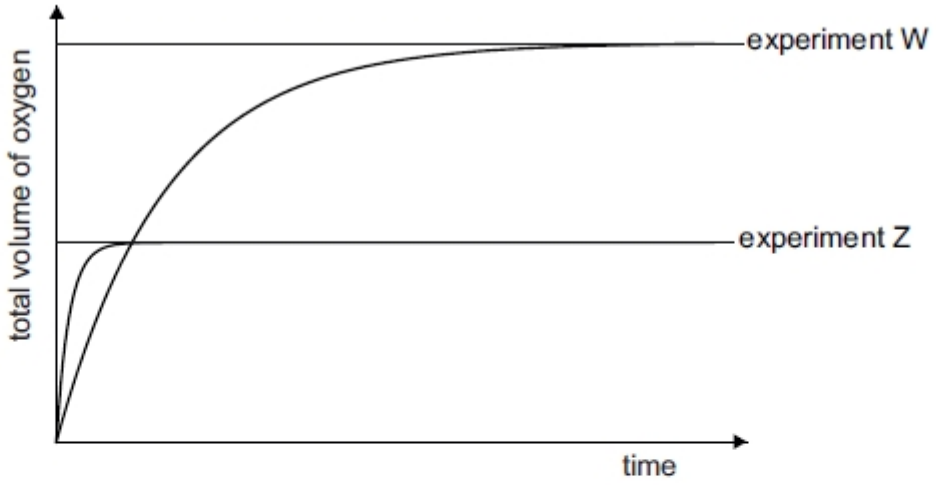
concentration of HCl

Which experiment (A-E) in the following table will produce 8.8 g of carbon dioxide in the shortest time?

(M_r values: $CaCO_3 = 100$; $CO_2 = 44$)

	$CaCO_3$		HCl	
	type	*mass* / g	*volume* / cm^3	*concentration* / $mol\,dm^{-3}$
A	chips	10	400	2.0
B	powder	20	100	2.0
C	chips	20	200	2.0
D	powder	10	200	2.0
E	chips	20	400	1.0

44 The graphs show results of two experiments (W and Z) involving the catalytic decomposition of hydrogen peroxide.



Assuming all other conditions are kept constant, which one of the following options would lead to the results shown?

	experiment W	*experiment Z*
A	100 cm^3 of 1.0 mol dm^{-3} hydrogen peroxide	50 cm^3 of 2.0 mol dm^{-3} hydrogen peroxide
B	catalyst is in lumps	catalyst is finely divided
C	reaction carried out at 25 °C	reaction carried out at 50 °C
D	2.0 g manganese(IV) oxide used	1.0 g manganese(IV) oxide used
E	100 cm^3 of 1.0 mol dm^{-3} hydrogen peroxide	25 cm^3 of 2.0 mol dm^{-3} hydrogen peroxide

41 The following equations represent the reactions of four metals M, Q, R and T:

$$M(s) + HCl(aq) \rightarrow \text{no reaction}$$

$$R(s) + TSO_4(aq) \rightarrow RSO_4(aq) + T(s)$$

$$M(s) + QNO_3(aq) \rightarrow MNO_3(aq) + Q(s)$$

$$T(s) + 2HCl(aq) \rightarrow TCl_2(aq) + H_2(g)$$

Which option lists the order of reactivity of the four metals, from the most to the least reactive?

A M, Q, R, T

B M, R, T, Q

C Q, M, T, R

D Q, R, T, M

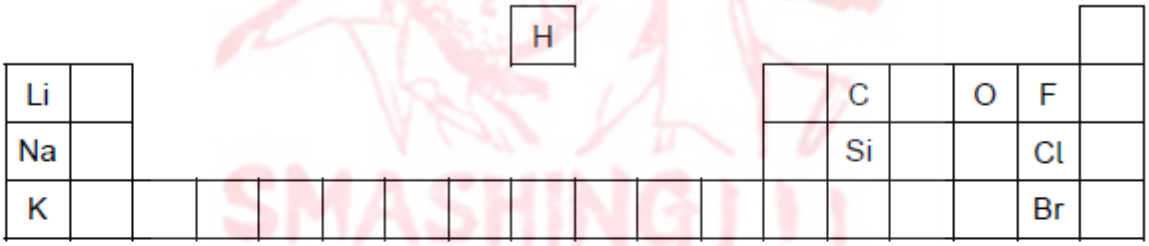
E R, M, T, Q

F R, T, M, Q

G T, M, R, Q

H T, R, Q, M

44 A portion of the Periodic Table is given:



Which one of these trends is correct?

A Boiling point: K > Na > Li

B Electrical conductivity: NaCl(l) > NaCl(s) > Na(s)

C Reactivity: $Br_2 > Cl_2 > F_2$

D Melting point: $SiO_2 > H_2O > Na_2O$

E Number of double bonds per molecule: $CO_2 > O_2 > H_2O$

46 An element has a mass number of 40 and an atomic number of 20.

Which statement(s) about this element is/are correct?

1 Its atomic nucleus has a relative mass of 20.

2 It is a noble gas.

3 It would form a negative ion.

4 It is in Group 2 of the Periodic Table.

5 It is a non-metallic element.

A 1, 2 and 3 only

B 1, 3 and 4 only

C 1, 4 and 5 only

D 2, 3 and 5 only

E 4 only

F 5 only

51 Listed are the electron configurations for the atoms of different elements.

Which one represents the most reactive non-metal?

A 2,4

B 2,6

C 2,7

D 2,8,1

E 2,8,6

F 2,8,7

47 Which of the following statements about elements in the Periodic Table is/are correct?

1 When the element in Period 5, Group 2 reacts with the element that is in Period 3, Group 17, a redox reaction occurs.

2 In each Group, the elements from Period 2 are more reactive than the elements from Period 5.

3 The compound formed between the element in Period 2, Group 14 and the element in Period 3, Group 17 will have a simple molecular structure.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

57 An experiment is carried out using the first three metals in Group 1: lithium, sodium and potassium.

The initial masses of three open beakers each containing 100 g samples of an alcohol are recorded.

In three separate experiments, equal small masses of lithium, sodium and potassium are added to the three beakers, which are on electronic balances.

Each metal reacts in a similar way and after the reaction is complete, the final mass of each beaker and its contents is recorded.

In each case, the final mass of the beaker and its contents is compared to the recorded initial mass before the alkali metal was added.

Which of the following statements is correct?

A The beaker with lithium added would decrease in mass the most.

B The beaker with sodium added would decrease in mass the most.

C The beaker with potassium added would decrease in mass the most.

D All three beakers would show the same decrease in mass.

E The beaker with lithium added would increase in mass the most.

F The beaker with sodium added would increase in mass the most.

G The beaker with potassium added would increase in mass the most.

H All three beakers would show the same increase in mass.

42 Consider **only** the first three metals in Group 1 (Li, Na, K) and **only** the first three elements in Group 17 (F, Cl, Br).

Which of the following statements is/are correct for the compound lithium bromide?

1 It is formed from the least reactive of the three Group 17 elements.

2 It is formed from the least reactive of the three Group 1 elements and the Group 17 element (of the three) with the lowest boiling point.

3 It is formed from the Group 1 element (of the three) with the highest melting point.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

47 Which of the following statements about elements in the Periodic Table is/are correct?

1 When the element in Period 5, Group 2 reacts with the element that is in Period 3, Group 17, a redox reaction occurs.

2 In each Group, the elements from Period 2 are more reactive than the elements from Period 5.

3 The compound formed between the element in Period 2, Group 14 and the element in Period 3, Group 17 will have a simple molecular structure.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

Question C1

Data: Assume that the molar gas volume = 24.0 $dm^3 mol^{-1}$ at room temperature and pressure (rtp).

This question concerns the chemistry of tellurium, an element in Group 16 of the Periodic Table.

a) What do you expect will be the maximum and minimum oxidation states of tellurium? Briefly explain your answer.

[3 marks]

Answer: .....

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b) How do the electronegativities of the elements vary on descending Group 16?

[1 mark]

Answer: .....

.....

c) Which hydride, H_2O or H_2Te, has the higher boiling point? Briefly explain your answer.

[2 marks]

Answer: .....

.....

.....

.....

41 The following information about metals labelled P, Q, R and S is given.

- Metals P and S can be extracted by electrolysis, but not by reaction with carbon.
- Metals Q and R can be extracted by reaction with carbon.
- Metal S forms positive ions more readily than metal P.
- Metal R reacts with the oxide of metal Q.

What is the order of reactivity of these four metals, starting with the most reactive?

A P, S, Q, R

B P, S, R, Q

C Q, R, P, S

D Q, R, S, P

E R, Q, P, S

F R, Q, S, P

G S, P, Q, R

H S, P, R, Q

51 In each of the following procedures an excess of the metal is added to 1.0 dm^3 of a 1.0 mol dm^{-3} solution of the acid.

copper added to sulfuric acid

iron added to hydrochloric acid

magnesium added to sulfuric acid

zinc added to hydrochloric acid

Which row in the following table identifies combinations of metal and acid that will react and produce the largest, and the smallest, theoretical mass of anhydrous salt?

(M_r values: $CuSO_4$ = 160; $FeCl_2$ = 127; $MgSO_4$ = 120; $ZnCl_2$ = 136)

	reaction that produces the largest mass of salt	*reaction that produces the smallest mass of salt*
A	Cu and H_2SO_4	Fe and HCl
B	Cu and H_2SO_4	Mg and H_2SO_4
C	Fe and HCl	Zn and HCl
D	Mg and H_2SO_4	Fe and HCl
E	Mg and H_2SO_4	Zn and HCl
F	Zn and HCl	Mg and H_2SO_4

42 Concentrated aqueous sodium chloride was electrolysed. After a few minutes, the remaining electrolyte solution was tested with a pH probe at 25 °C.

The gases produced at the electrodes were collected and tested with a colourless aqueous solution of sodium bromide.

Which row in the following table best describes the observations in these tests?

	pH of the remaining solution	*test of gas from anode (positive electrode)*	*test of gas from cathode (negative electrode)*
A	2	no observable change	no observable change
B	2	no observable change	orange solution forms
C	7	orange solution forms	no observable change
D	7	orange solution forms	orange solution forms
E	12	orange solution forms	no observable change
F	12	no observable change	orange solution forms

44 X, Y and Z have the **same** electron configuration.

X is an atom, Y is a monatomic anion and Z is a monatomic cation.

Which of the following statements is **always** correct?

A Anion Y has fewer protons than atom X.

B Cation Z has more electrons than protons.

C X, Y and Z are in the same group of the Periodic Table.

D X, Y and Z have consecutive atomic numbers.

E X, Y and Z have the same mass number.

46 The non-metallic element phosphorus forms two stable chlorides: PCl_3 (boiling point 76 °C) and PCl_5 (boiling point 161 °C).

Which of the following statements explain(s) the difference in boiling points?

1 There are more covalent bonds in PCl_5 so more energy is required to break them.

2 The forces between the molecules in liquid PCl_5 are stronger.

3 The covalent bonds in PCl_3 are weaker so less energy is required to break them.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

42 Element X has atomic number 20. Consider only the **simple oxide** of X.

Which of the following options identifies the formula, the type of bonding and the acid-base character of the oxide of element X?

	formula of oxide	*type of bonding in oxide*	*acid-base character of oxide*
A	X_2O	ionic	basic
B	X_2O	covalent	basic
C	XO	ionic	basic
D	XO	covalent	acidic
E	XO_2	ionic	acidic
F	XO_2	covalent	acidic
G	X_2O_3	ionic	basic
H	X_2O_3	covalent	acidic

42 An element has a mass number of 40 and an atomic number of 20.

Which statement(s) about this element is/are correct?

1 Its atomic nucleus has a relative mass of 20.

2 It is a noble gas.

3 It would form a negative ion.

4 It is in group 2 of the periodic table.

5 It is a non-metallic element.

A 1, 2 and 3 only

B 1, 3 and 4 only

C 1, 4 and 5 only

D 2, 3 and 5 only

E 4 only

F 5 only

47 Listed are the electronic configurations for the atoms of different elements.

Which one represents the most reactive non-metal?

A 2, 4

B 2, 6

C 2, 7

D 2, 8, 1

E 2, 8, 6

F 2, 8, 7

A Level Topic # 11 **Q# 205/ Cambridge/2020/Section 2/ www.SmashingScience.org**

42 Consider **only** the first three metals in Group 1 (Li, Na, K) and **only** the first three elements in Group 17 (F, Cl, Br).

Which of the following statements is/are correct for the compound lithium bromide?

1 It is formed from the least reactive of the three Group 17 elements.

2 It is formed from the least reactive of the three Group 1 elements and the Group 17 element (of the three) with the lowest boiling point.

3 It is formed from the Group 1 element (of the three) with the highest melting point.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

55 The equation shows the complete combustion of an alkane.

$$\text{alkane} + aO_2 \rightarrow bCO_2 + cH_2O$$

100 cm^3 of a gaseous alkane requires 650 cm^3 of oxygen for complete combustion. The volumes of both gases were measured at the same temperature and pressure.

What is the value of $a + b + c$?

A 10.5

B 12

C 14

D 15.5

E 17.5

F 19

59 One mole of an unsaturated hydrocarbon reacts with exactly one mole of bromine to form a compound that contains $\frac{6}{15}$ carbon, $\frac{1}{15}$ hydrogen and $\frac{8}{15}$ bromine by mass.

What is the relative molar mass (M_r) of this product?

(A_r values: C = 12; H = 1; Br = 80)

A 150

B 210

C 220

D 290

E 300

F 420

G 440

H 713

54 1 mol of compound X undergoes complete combustion to produce 144 dm^3 of carbon dioxide (measured at room temperature and pressure).

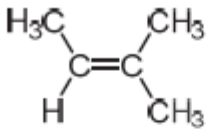
1 mol of X can also undergo an addition reaction with 1 mol of hydrogen to form a saturated compound that has one branch.

X undergoes addition polymerisation. A section of the addition polymer containing three repeating units has an M_r value greater than 200 but less than 300.

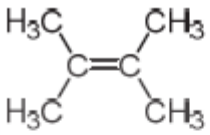
Which one of the following structural formulae could be that of compound X?

(A_r values: C = 12; H = 1; F = 19. Assume that one mole of any gas occupies a volume of 24 dm^3 at room temperature and pressure.)

A



B



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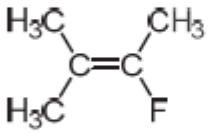

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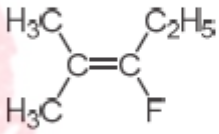
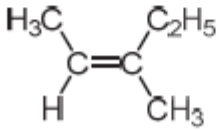


E



59 One mole of an unsaturated hydrocarbon reacts with exactly one mole of bromine to form a compound that contains $\frac{6}{15}$ carbon, $\frac{1}{15}$ hydrogen and $\frac{8}{15}$ bromine by mass.

What is the relative molar mass (M_r) of this product?

(A_r values: C = 12; H = 1; Br = 80)

A 150

B 210

C 220

D 290

E 300

F 420

G 440

H 713

44 Molecule J is a straight-chain hydrocarbon containing one carbon-carbon double bond.

The relative atomic mass (A_r) of hydrogen is 1 and carbon is 12.

What is the **minimum** additional information that is needed in order to determine the molecular formula of molecule J?

1 The percentage by mass of carbon in the molecule.

2 The percentage by mass of hydrogen in the molecule.

3 The relative molar mass (M_r) of the molecule.

A 1 only

B 3 only

C 1 and 2 only

D 1 and 3 only

E 1, 2 and 3

55 Complete combustion of 1 mol of hydrocarbon X requires exactly 8.5 mol of oxygen.

Incomplete combustion of 1 mol of hydrocarbon X, to form carbon monoxide and water only, requires exactly 5.5 mol of oxygen.

How many hydrogen atoms are there in one molecule of hydrocarbon X?

A 6

B 8

C 10

D 12

E 14

Question C2

Trifluoroethanoic acid, TFEA, is a carboxylic acid often used in organic chemistry and has the formula CF_3COOH. The density of TFEA is $1.489\,g\,cm^{-3}$.

a) Draw the structure for trifluoroethanoic acid (TFEA). Indicate on your structure the approximate bond angles around each carbon.

[2 marks]

Answer:

37 HBr reacts with pent-2-ene in an addition reaction.

Which of the following products is/are formed in the reaction?

1 $CH_3CHBrCH_2CH_2CH_3$

2 $CH_2BrCH_2CH_2CH_2CH_3$

3 $CH_3CH_2CHBrCH_2CH_3$

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

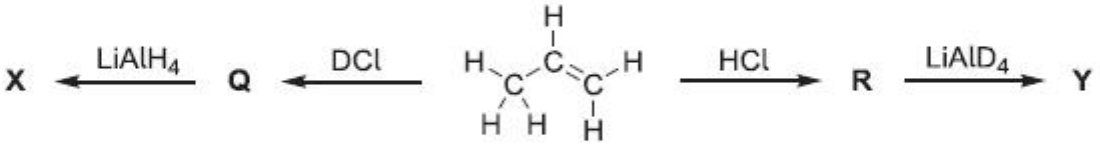
F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

d) Lithium aluminium deuteride can be prepared if deuterium gas is used in place of normal hydrogen. Deuterium, often given the symbol D, is the non-radioactive isotope of hydrogen, i.e. D = ^{2}H. The formula for lithium aluminium deuteride can be written $LiAlD_4$. Both $LiAlH_4$ and $LiAlD_4$ are common reducing agents and the latter is useful for preparing deuterium-containing compounds.

Isomers of mono-deuterated propane, **X** and **Y**, may be prepared from propene according to the following scheme which also uses hydrogen chloride, HCl, and deuterium chloride, DCl. In the scheme, only the carbon-containing compounds are shown; other by-products are not.



Give the structures of **X** and **Y** and the intermediates **Q** and **R** formed during the syntheses.

[4 marks]

Answer:

e) 2,2-dideuterated propane may be prepared easily in two steps, from a mono-deuterated propene, **Z**. (The formula for **Z** is C_3H_5D.)

(i) Draw the structures of all the alkenes with formula C_3H_5D. **[2 marks]**

Answer:

(ii) Give a synthesis of 2,2-dideuterated propane starting from **Z** showing reagents and intermediates in each step, making sure to give the displayed formula for **Z**. **[3 marks]**

Answer: .....

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Question 3

a) There are two compounds with the formula C_3H_6. Write out the structures of these molecules as a displayed formula and as a skeletal formula. Give the names of the two compounds and identify the particular class of compounds each belongs to. **[4 marks]**

Answer: .....

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b) Like every other member in its class, one isomer of C_3H_6, isomer **A**, reacts rapidly with bromine to form a single product, **F**. Draw the structure of **A** as a skeletal formula and also the structure of the product formed when **A** reacts with bromine. **[3 marks]**

Answer: .....

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c) The second isomer of C_3H_6, isomer **B**, has a number of unique properties. The other members in the same class of compounds only react with bromine in the presence of light and form HBr as a side product. However, **B** reacts with bromine in the absence of light (but much less rapidly than **A**) and forms a single compound **G**. **F** and **G** are isomers. Draw the structures of **B** and **G** as skeletal formulae. **[4 marks]**

Answer: .....

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Question 4

There are six isomers with the formula C_5H_{10} that are alkenes. The alkenes all have different enthalpies of formation, all of which are negative.

a) Draw the structures of the six alkenes (skeletal or displayed structures are acceptable).

[6 marks]

Answer:

Samples of the six alkenes, in a random order, are labelled **P**, **Q**, **R**, **S**, **T**, and **U**. You will be able to identify which isomer *some* of these correspond to using the information and data throughout the rest of the question.

Alkenes **P**, **Q**, and **R** react with hydrogen gas and a metal catalyst to give the same alkane **A**; alkenes **S**, **T**, and **U** react under the same conditions to give a different alkane **B**.

Both alkanes **A** and **B** react with chlorine gas under UV light to form chloroalkanes with the formula $C_5H_{11}Cl$. Under such conditions, alkane **A** forms *four* different structural isomers, whereas **B** gives *three*.

b) Draw the structures of alkanes **A** and **B**. Also draw the structures of the four isomers arising from the chlorination of **A**, and the three isomers arising from the chlorination of **B**. **[6 marks]**

Answer:

Samples of the six alkenes, in a random order, are labelled **P**, **Q**, **R**, **S**, **T**, and **U**. You will be able to identify which isomer *some* of these correspond to using the information and data throughout the rest of the question.

Alkenes **P**, **Q**, and **R** react with hydrogen gas and a metal catalyst to give the same alkane **A**; alkenes **S**, **T**, and **U** react under the same conditions to give a different alkane **B**.

Both alkanes **A** and **B** react with chlorine gas under UV light to form chloroalkanes with the formula $C_5H_{11}Cl$. Under such conditions, alkane **A** forms *four* different structural isomers, whereas **B** gives *three*.

The alkenes react with HBr to form bromoalkanes with the formula $C_5H_{11}Br$; the reaction proceeds via a carbocation intermediate. Alkenes **S** and **T** give a mix of *two* structural isomers, whereas alkene **U** gives only one.

c) Give the structure of alkene **U**. **[4 marks]**

Answer:

A general rule for isomeric alkenes is that the more carbon atoms directly bonded to the double bond (or the lower the number of hydrogen atoms directly bonded), the more negative (that is, the more exothermic) the enthalpy of formation of the alkene.

d) Out of **P**, **Q** and **R**, **R** has the most negative (most exothermic) enthalpy of formation. Give the structure of **R**. **[1 mark]**

Answer:

Consider the following thermodynamic data:

	value / kJ mol^{-1}
standard enthalpy change of hydrogenation for alkene **P**	–113
standard enthalpy change of hydrogenation for alkene **Q**	–119
standard enthalpy change of combustion for alkane **A**	–3528
standard enthalpy change of formation of $H_2O(l)$	–286

e) Use the data to deduce the structure of: **(i)** alkene **P**; and **(ii)** alkene **Q**. **[4 marks]**

Answer: .....

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15 Tollens' reagent, $[Ag(NH_3)_2]NO_3(aq)$, can be used to coat glass surfaces with silver metal (A_r = 108) to make decorative objects. It is a reducing agent and reacts by oxidising aldehydes to carboxylic acids.

The half-equation for the organic oxidation can be represented as (R = alkyl group):

$$\underset{\text{aldehyde}}{RCHO} + H_2O \rightarrow \underset{\substack{\text{carboxylic}\\ \text{acid}}}{RCOOH} + 2H^+ + 2e^-$$

All of the inside surface of a beaker is to be coated in a uniform layer of silver metal of thickness 0.01 cm. The beaker can be modelled as a cylinder of height 10 cm and radius 5 cm.

The density of silver metal is 10.5 g cm^{-3}.

Which of the following expressions gives the minimum number of moles of aldehyde required?

(Assume that the yield of any reaction is 100%.)

A $\dfrac{10.5 \times 1.25 \times \pi}{2 \times 108}$

B $\dfrac{10.5 \times 1.25 \times \pi}{108}$

C $\dfrac{2 \times 10.5 \times 1.25 \times \pi}{108}$

D $\dfrac{108 \times 10.5 \times 1.25 \times \pi}{2}$

E $\dfrac{10.5 \times 1.5 \times \pi}{2 \times 108}$

F $\dfrac{2 \times 10.5 \times 1.5 \times \pi}{108}$

G $\dfrac{10.5 \times 1.5 \times \pi}{108}$

H $\dfrac{108 \times 10.5 \times 1.5 \times \pi}{2}$

23 Propanal can be reduced to propan-1-ol with hydrogen gas at high pressure and a platinum catalyst.

Radioactive propan-1-ol can be made if the hydrogen gas is replaced by pure tritium gas. Tritium, ^{3}H, is the radioactive isotope of hydrogen.

All of the atoms other than ^{3}H in the radioactive propan-1-ol are the most abundant isotope for the element. The most abundant isotopes of carbon, hydrogen and oxygen are ^{12}C, ^{1}H and ^{16}O.

How many neutrons are there in one molecule of this radioactive propan-1-ol?

A 26

B 28

C 30

D 32

E 34

F 40

G 42

33 A yellow precipitate is formed when alkaline aqueous iodine reacts with alcohols that have the structure R-CH(OH)CH_3, where R is a carbon chain or H.

There are a number of structural isomers with the molecular formula $C_5H_{12}O$ that are alcohols.

Of these structural isomeric alcohols:

(i) how many will form a yellow precipitate when reacted with alkaline aqueous iodine;

(ii) how many, following mild oxidation and immediate distillation, will produce a silver mirror with Tollens' reagent?

	(i) *forms yellow precipitate*	(ii) *produces silver mirror*
A	1	1
B	2	3
C	2	4
D	2	7
E	3	3
F	3	4
G	3	7
H	4	4

48 Bromine is an element in Group 17 of the Periodic Table.

Which of the following statements is/are correct about the element bromine?

1 Bromine will oxidise chloride ions in aqueous solution to form chlorine.

2 Bromine has a lower boiling point than chlorine.

3 Bromine reacts with calcium (Group 2) to form a compound containing 80% bromine by mass.

(A_r values: Cl = 35.5; Ca = 40; Br = 80)

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

A Level Topic # 18 **Q# 223/ Cambridge/2022/Section 2/ www.SmashingScience.org**

49 Carboxylic acid X reacts with propanol in the presence of an acid catalyst to form compound Y.

Compound Y has a relative molar mass of 116.

What is the relative molar mass (M_r) of X?

(A_r values: C = 12; H = 1; O = 16)

A 45

B 46

C 55

D 56

E 59

F 60

G 73

H 74

49 Carboxylic acid X reacts with propanol in the presence of an acid catalyst to form compound Y.

Compound Y has a relative molar mass of 116.

What is the relative molar mass (M_r) of X?

(A_r values: C = 12; H = 1; O = 16)

A 45

B 46

C 55

D 56

E 59

F 60

G 73

H 74

49 The table shows the reagents in three organic reactions.

Which of the rows correctly show(s) the product(s) obtained from the specified reactants?

	reactants	*product(s)*
1	$CH_3CH{=}CH_2$ and HBr	1,2-dibromopropane (only)
2	C_2H_5COOH and CH_3OH, in the presence of an $H^+(aq)$ catalyst	methyl propanoate and water
3	C_2H_5OH and Na	sodium ethanoate and hydrogen

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

54 1 mol of compound X undergoes complete combustion to produce 144 dm^3 of carbon dioxide (measured at room temperature and pressure).

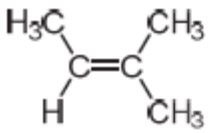
1 mol of X can also undergo an addition reaction with 1 mol of hydrogen to form a saturated compound that has one branch.

X undergoes addition polymerisation. A section of the addition polymer containing three repeating units has an M_r value greater than 200 but less than 300.

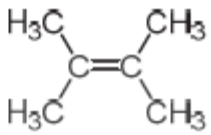
Which one of the following structural formulae could be that of compound X?

(A_r values: C = 12; H = 1; F = 19. Assume that one mole of any gas occupies a volume of 24 dm^3 at room temperature and pressure.)

A



B



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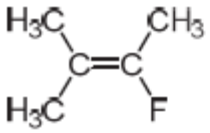

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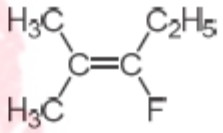
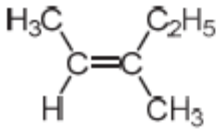
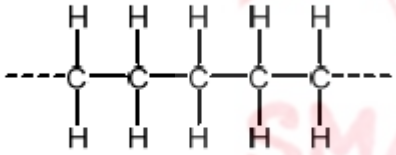


E



46 Which one of the following represents the repeating unit of poly(pent-2-ene)?

A



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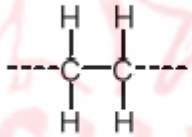
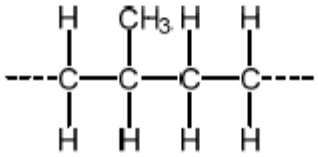


C



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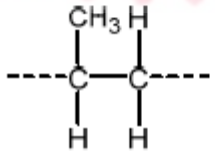
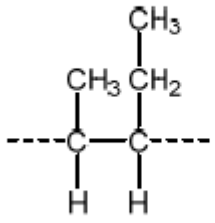


E



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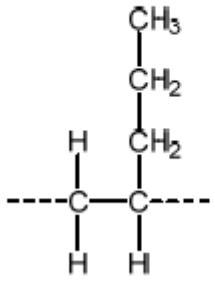


18 Compound P, with molecular formula C_5H_{10}, reacts with hydrogen bromide in an addition reaction to form compound Q as the only major product.

Q undergoes a substitution reaction with aqueous sodium hydroxide to form compound R.

After R is completely oxidised using acidified potassium dichromate(VI), the resulting product does **not** react with aqueous sodium carbonate.

R undergoes an elimination reaction to form a mixture of products: P and S.

S has no stereoisomers.

What is compound P?

A pent-1-ene

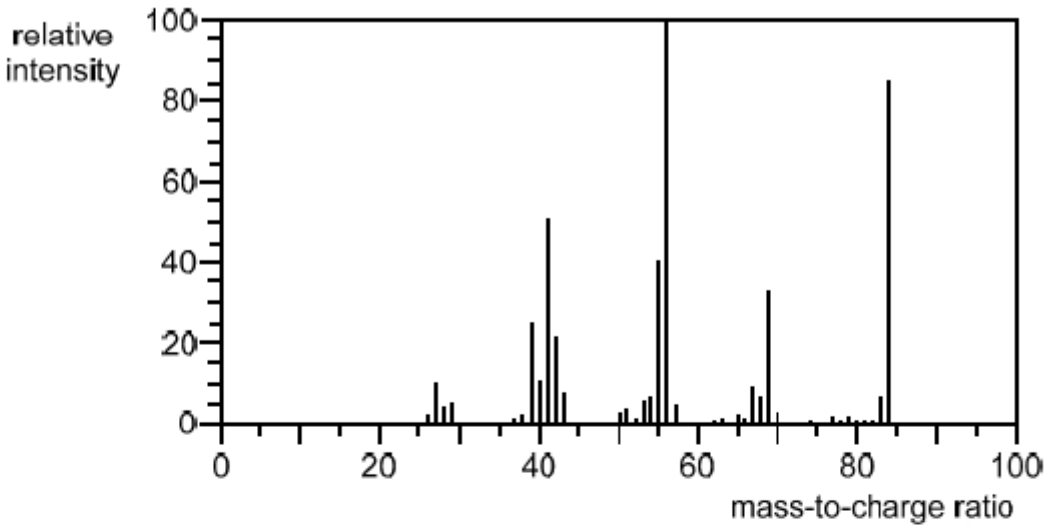
B pent-2-ene

C 2-methylbut-1-ene

D 2-methylbut-2-ene

E 3-methylbut-1-ene

13 The mass spectrum of a hydrocarbon, X, is shown.



X contains 14.3% by mass of hydrogen and does **not** decolourise aqueous bromine.

Which of the following could be the identity of X?

1 hex-2-ene

2 cyclohexane

3 cyclobutane

(A_r values: H = 1; C = 12)

A 1 only

B 2 only

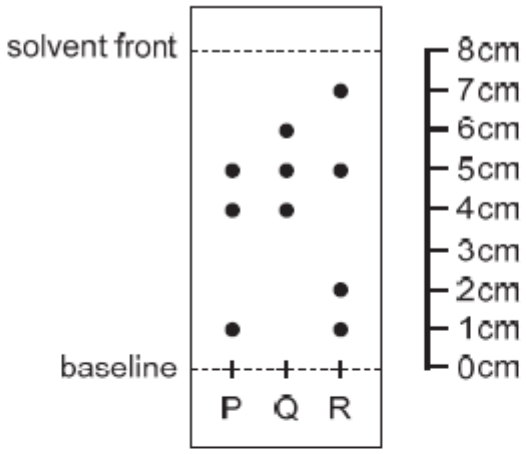
C 3 only

D 1 and 2 only

E 1 and 3 only

F 2 and 3 only

51 Three mixtures (P, Q and R) of amino acids were separated using paper chromatography.



The test was repeated with the same mixtures, paper and solvent but this time the distance travelled by the common component of the mixtures was 7.5 cm.

How far did the most mobile component of mixture Q travel in the second test?

A 6.0 cm

B 8.5 cm

C 9.0 cm

D 9.6 cm

E 10.5 cm

F 12.0 cm

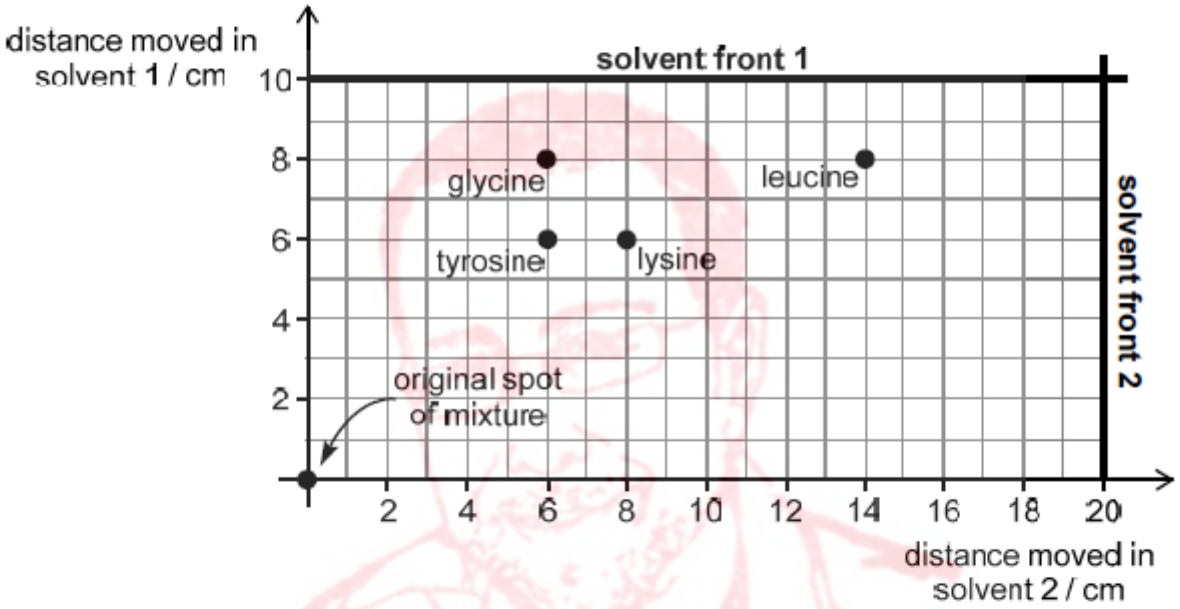
51 An experiment was carried out to separate the four amino acids present in a mixture of amino acids.

A spot of this mixture was placed on chromatography paper. The bottom of the paper was placed in solvent 1 and left until the solvent nearly reached the top of the paper.

The paper was then thoroughly dried and turned by 90°. The procedure was then repeated with solvent 2.

The amino acids were then identified with reference to known R_f values in the respective solvents.

The final positions of the amino acids on the chromatograph are shown on the following diagram.



Which of the following statements is correct?

A Leucine travels further relative to the solvent front in solvent 2 than in solvent 1.

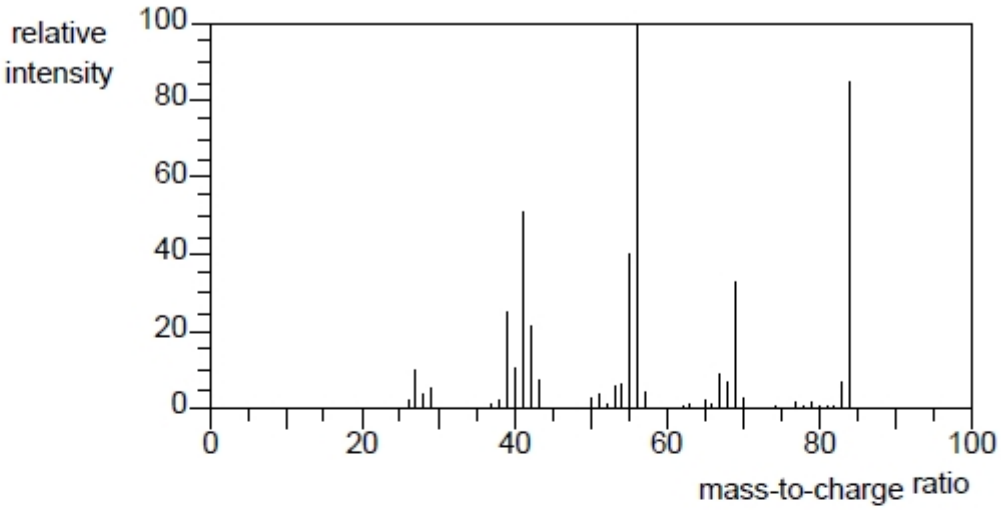
B Lysine has a greater R_f value in solvent 1 than it has in solvent 2.

C Solvent 1 alone could be used to separate all four amino acids.

D Solvent 2 alone could be used to separate all four amino acids.

E The R_f value of tyrosine in solvent 1 is 0.6 and in solvent 2 is 0.7.

13 The mass spectrum of a hydrocarbon, X, is shown.



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Which of the following could be the identity of X?

1 hex-2-ene

2 cyclohexane

3 cyclobutane

(A_r values: H = 1; C = 12)

A 1 only

B 2 only

C 3 only

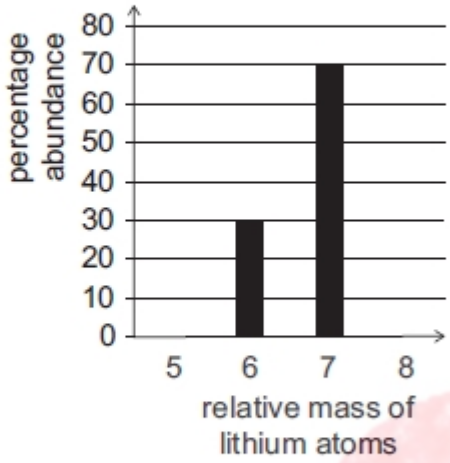
D 1 and 2 only

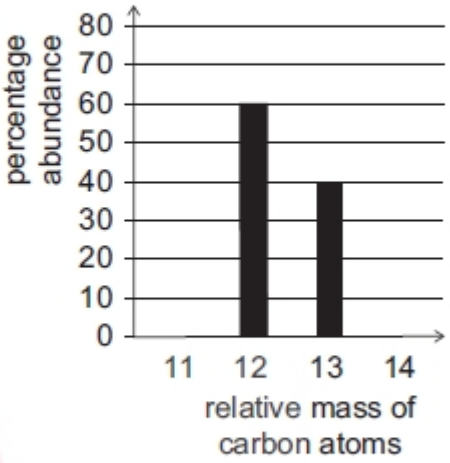
E 1 and 3 only

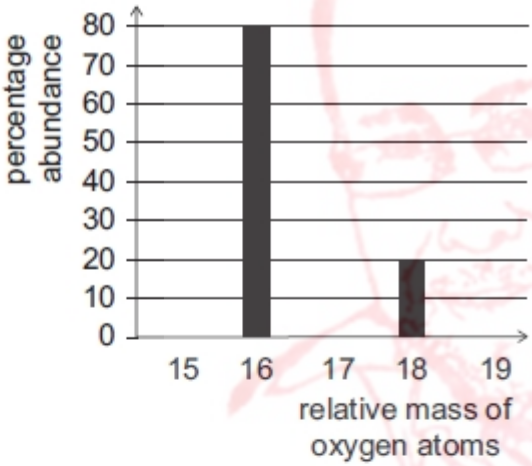
F 2 and 3 only

40 A mass spectrometer is a device that can measure the mass of isotopes. It shows this data as a spectrum, giving both the relative mass and the percentage abundance of each isotope.

The charts indicate the relative mass and percentage abundance for lithium atoms, carbon atoms and oxygen atoms found in a sample taken from a nuclear reactor.







Using this data, what is the largest possible relative molar mass of lithium carbonate?

A 35

B 38

C 45

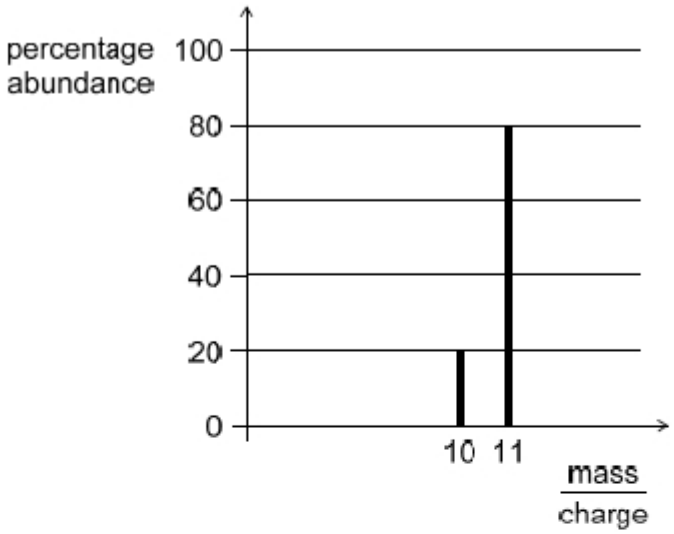
D 67

E 74

F 75

G 81

40 A mass spectrum of a sample of element X with atomic number 5 is shown.



Using the data, which row in the following table best describes the position of X in the Periodic Table and the relative atomic mass of this sample of X?

	Period	*Group*	*relative atomic mass*
A	1	15	10.2
B	1	15	10.8
C	2	13	10.2
D	2	13	10.8
E	3	2	10.2
F	3	2	10.8

48 Naturally occurring chlorine is a mixture of two isotopes with mass number 35 and 37. The isotope with mass number 35 is three times as common as the isotope with mass number 37.

Naturally occurring bromine is a mixture of two isotopes with mass numbers 79 and 81. They are present in equal amounts.

What fraction of the naturally occurring compound CH_2BrCl has a relative molecular mass of 128?

(A_r: H = 1; C = 12)

A $\frac{1}{8}$

B $\frac{1}{4}$

C $\frac{3}{8}$

D $\frac{1}{2}$

E $\frac{5}{8}$

A Level Topic # 23 **Q# 236/ Cambridge/2021/Section 2/ www.SmashingScience.org**

39 Lanthanum iodate(V), $La(IO_3)_3$, decomposes when heated to 600 °C to give a product that contains the ion Q.

An **unbalanced** ionic equation for the reaction is:

$$IO_3^- \rightarrow \text{ion Q} + I_2 + O_2$$

Ion Q contains only iodine in the +7 oxidation state and oxygen in the –2 oxidation state.

The oxidation state of the lanthanum does not change in the reaction.

0.005 mol of $La(IO_3)_3$ is fully decomposed by heating. The iodine produced is titrated against a 0.4 mol dm^{-3} solution of sodium thiosulfate ($Na_2S_2O_3$). 30.0 cm^3 of the sodium thiosulfate solution is needed to reach the end-point. The equation for the reaction between iodine and sodium thiosulfate is:

$$I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6$$

What is the formula of the product that contains ion Q?

A $LaIO_5$

B $LaIO_6$

C $La(IO_4)_3$

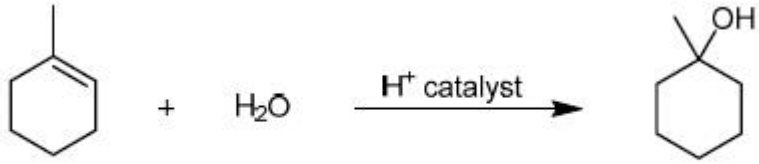
D $La_3(IO_6)_5$

E $La_5(IO_4)_3$

F $La_5(IO_6)_3$

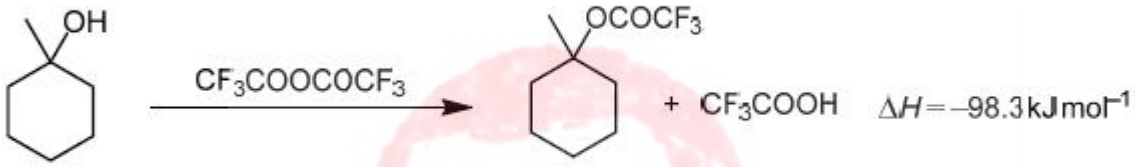
A mixture of TFEA and trifluoroethanoic anhydride, $CF_3COOCOCF_3$, was used as the solvent system in a series of experiments to determine the standard enthalpy changes of hydration of various alkenes.

1-methylcyclohexene, **A**, may be hydrated in an acid-catalysed reaction as shown below:



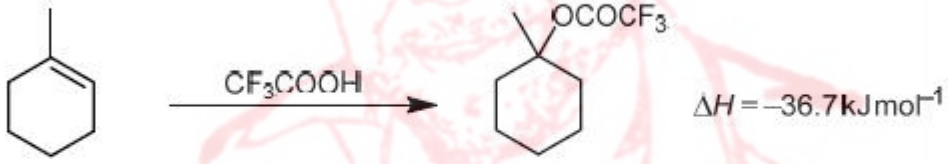
A **B**

In a mixture of TFEA and trifluoroethanoic anhydride, **B** reacts with the trifluoroethanoic anhydride to form **C** and TFEA as shown below. The standard enthalpy change for this reaction is –98.3 kJ mol^{-1}.



B **C**

Compound **C** may also be formed in the same mixture of TFEA and trifluoroethanoic anhydride from the reaction between 1-methylcyclohexene and TFEA. The standard enthalpy change for this reaction is –36.7 kJ mol^{-1}.



A **C**

The standard enthalpy change for the reaction between one mole of water and one mole of trifluoroethanoic anhydride is –75.6 kJ mol^{-1}.

j) Give the equation for the reaction between one mole of water and one mole of trifluoroethanoic anhydride.

[1 mark]

Answer: .....

.....

.....

k) By constructing an appropriate energy cycle, calculate the standard enthalpy change for the hydration of alkene **A**.

[4 marks]

Answer: .....

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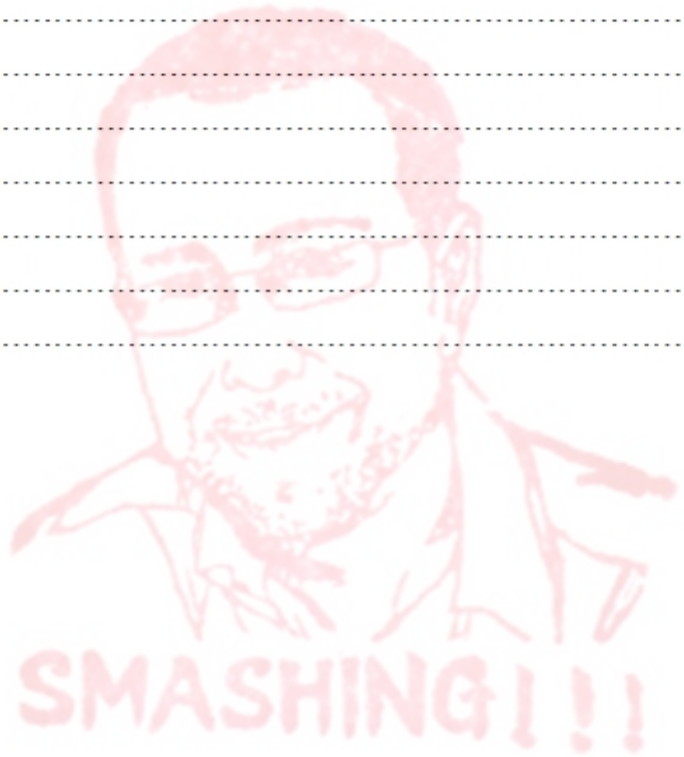


Question C2

Read the following carefully before proceeding to answer the question.

In their solid (crystalline) form many inorganic salts (such as NaCl or MgF_2) can be thought of as consisting of a giant lattice in which positive ions (e.g. Na^+, Mg^{2+}) and negative ions (e.g. Cl^-, F^-) are arranged in a regular pattern, called a *lattice*. The ions are held together by electrostatic forces arising from the favourable interactions between ions of opposite charge.

The lattice enthalpy is the enthalpy change for a process in which the **solid** material is formed from ions in the gas phase. For NaCl(s) this is the process

$$Na^+(g) + Cl^-(g) \rightarrow NaCl(s)$$

and for MgF_2 the process is

$$Mg^{2+}(g) + 2F^-(g) \rightarrow MgF_2(s)$$

The lattice enthalpy is invariably large and negative.

The lattice enthalpy in $kJ\,mol^{-1}$ can be estimated using the following expression:

$$\frac{-1.07\times10^5\times n_{ions}\times z_+\times z_-}{r_+ + r_-}$$

Equation 1

In this expression, r_+ is the radius of the positive ion, in pm ($1\,pm = 10^{-12}\,m$), and r_- is the radius of the negative ion, also given in pm.

n_{ions} is the number of ions in the formula unit; for example, for NaCl $n_{ions}=2$, but for MgF_2 $n_{ions}=3$.

z_+ is the charge number on the positive ion; for example for Na^+ it is 1, but for Mg^{2+} it is 2. Likewise z_- is the **absolute value** of the charge number on the negative ion: for Cl^- it is 1 (**not** −1).

a) Use Equation 1 to calculate the lattice enthalpy for CuF_2 given the following data:

$$r_+ = 73\,\text{pm},\ r_- = 133\,\text{pm}$$

[3 marks]

Answer: .....

.....

.....

.....

.....

.....

b) Use Equation 1 to calculate the lattice enthalpy for CuF_3 given the following data:

$$r_+ = 54\,\text{pm},\ r_- = 133\,\text{pm}$$

[3 marks]

Answer: .....

.....

.....

.....

.....

.....

c) Calculated values of the lattice enthalpy can be used to estimate the enthalpy change of hypothetical reactions, such as

$$CuF_2(s) + \frac{1}{2}F_2(g) \rightarrow CuF_3(s) \qquad \textbf{Equation 2}$$

Determine the oxidation state of copper in each of the species and hence classify what kind of reaction this is. **[3 marks]**

Answer: .....

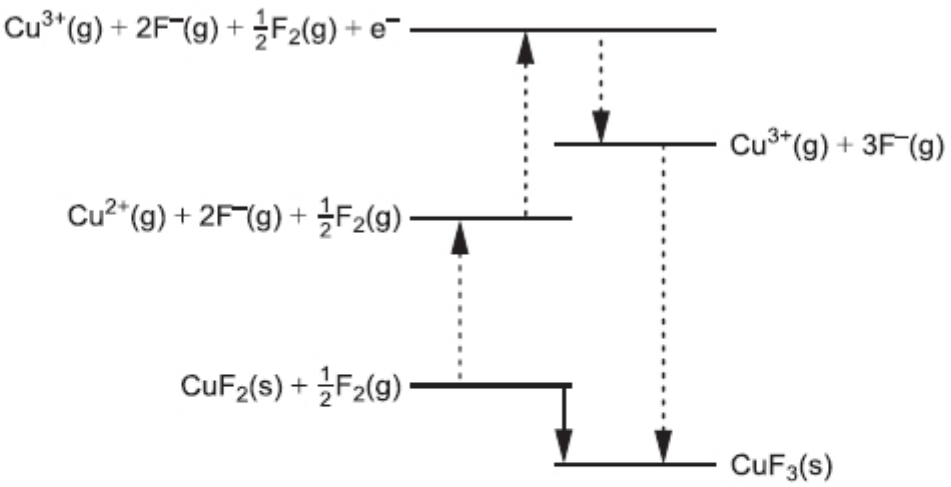
.....

.....

.....

.....

d) The enthalpy change for the reaction in Equation 2 can be calculated using the following Hess's Law cycle.



Using your results from **a)** and **b)**, and given the following enthalpy changes

$$F_2(g) + 2e^- \rightarrow 2F^-(g) \qquad \Delta H = -540\,kJ\,mol^{-1}$$
$$Cu^{2+}(g) \rightarrow Cu^{3+}(g) + e^- \qquad \Delta H = 3555\,kJ\,mol^{-1}$$

calculate the enthalpy change for:

$$CuF_2(s) + \frac{1}{2}F_2(g) \rightarrow CuF_3(s)$$

[5 marks]

Answer: .....

e) Use the data given below to calculate the enthalpy change for the following reaction (M is an unspecified metallic element).

$$2MF_2(s) \rightarrow MF_3(s) + MF(s)$$

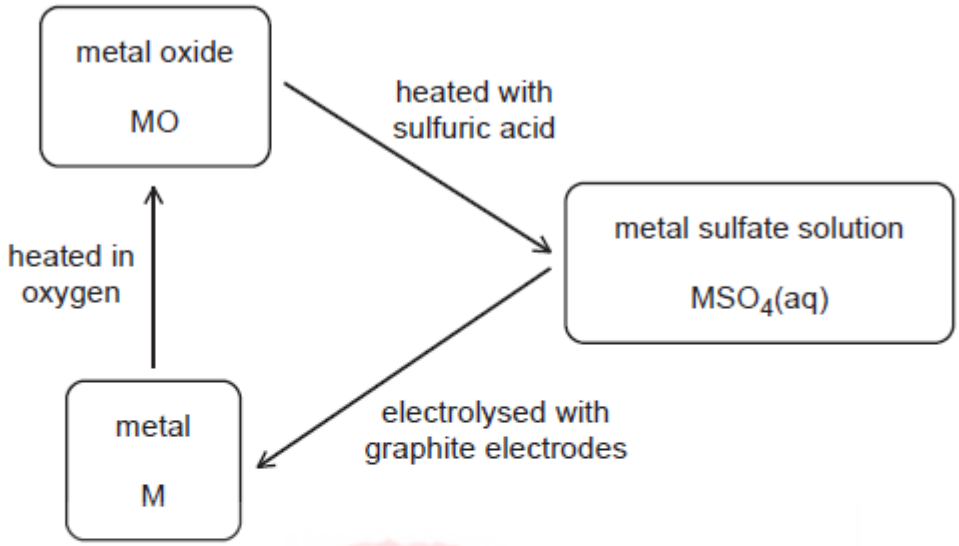
You may find it helpful to start by constructing an appropriate Hess's Law cycle.

$MF_2(s) \rightarrow M^{2+}(g) + 2F^-(g)$	$\Delta H = 3000\,kJ\,mol^{-1}$
$MF_3(s) \rightarrow M^{3+}(g) + 3F^-(g)$	$\Delta H = 7000\,kJ\,mol^{-1}$
$MF(s) \rightarrow M^{+}(g) + F^-(g)$	$\Delta H = 1000\,kJ\,mol^{-1}$
$M^{+}(g) \rightarrow M^{2+}(g) + e^-$	$\Delta H = 2000\,kJ\,mol^{-1}$
$M^{2+}(g) \rightarrow M^{3+}(g) + e^-$	$\Delta H = 3000\,kJ\,mol^{-1}$

[6 marks]

Answer: .....

42 Some reactions of metal M and its compounds are shown in the following diagram.



Which one of the following could be the identity of metal M?

A aluminium

B copper

C magnesium

D potassium

E silver

44 Which of the following statements about losing electrons is/are correct?

1 During the electrolysis of a molten binary compound the ions attracted to the cathode (negative electrode) lose electrons at that electrode.

2 Descending Group 1 of the Periodic Table from lithium to caesium, the atoms of the elements lose electrons more easily.

3 When a substance is acting as a reducing agent it loses electrons.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

47 Concentrated aqueous solutions of three compounds are electrolysed with inert electrodes

The constituent elements of which of the following compounds may be collected using this process?

1 copper(II) bromide

2 hydrogen chloride

3 potassium chloride

A none of them

B 1 only

C 2 only

D 3 only

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F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

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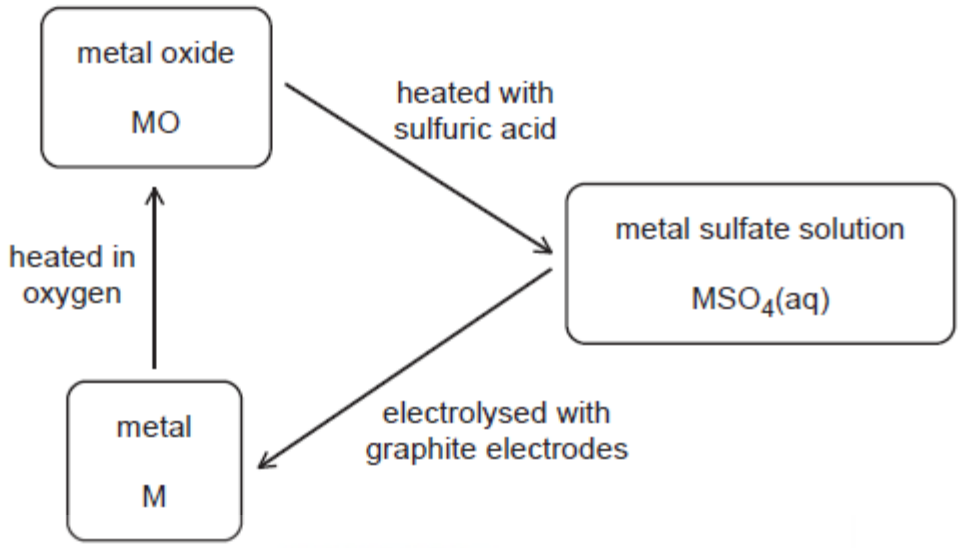

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57 The electrolysis of molten potassium chloride in an inert atmosphere produces potassium at the negative electrode and chlorine at the positive electrode.

The electrolysis of aqueous copper(II) sulfate solution deposits copper on the negative electrode.

The masses of potassium, chlorine and copper produced or deposited in these experiments were recorded.

Assume that the same number of electrons is transferred during the electrolysis of molten potassium chloride and aqueous copper(II) sulfate solution.

Which of the following gives the elements arranged in order of the mass produced/deposited during these electrolysis experiments, from lowest mass to highest mass?

(A_r values: Cl = 35.5; K = 39.0; Cu = 63.5)

A chlorine, copper, potassium

B chlorine, potassium, copper

C copper, chlorine, potassium

D copper, potassium, chlorine

E potassium, chlorine, copper

F potassium, copper, chlorine

42 When concentrated aqueous sodium chloride solution is electrolysed using inert electrodes a reaction occurs at each electrode.

Which is the correct combination of elements actually produced at the electrodes in this electrolysis?

A positive electrode = chlorine; negative electrode = hydrogen

B positive electrode = chlorine; negative electrode = sodium

C positive electrode = oxygen; negative electrode = hydrogen

D positive electrode = oxygen; negative electrode = sodium

E positive electrode = sodium; negative electrode = chlorine

48 Some dilute aqueous solutions were electrolysed using graphite electrodes.

Which of the rows in the table show(s) the correct products of electrolysis?

	aqueous electrolyte	*products of electrolysis*	
		at the cathode (negative electrode)	*at the anode (positive electrode)*
1	potassium hydroxide	potassium	oxygen
2	copper(II) chloride	chlorine	copper
3	sodium sulfate	hydrogen	sulfur

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

59 An electric current is the flow of charged particles.

In an electrolysis of aluminium oxide using inert electrodes, the current flows at 5.00×10^{-6} moles of electrons per second.

Assume that only aluminium oxide is present and the aluminium is a single isotope $^{27}_{13}Al$.

What mass of aluminium is produced in 48 seconds?

A 0.04 mg

B 0.09 mg

C 0.52 mg

D 1.04 mg

E 1.08 mg

F 2.16 mg

G 3.12 mg

H 6.48 mg

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C 2 only

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F 1 and 3 only

G 2 and 3 only

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D 1.04 mg

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F 2.16 mg

G 3.12 mg

H 6.48 mg

46 In the electrolysis of dilute sulfuric acid, hydrogen gas is formed at the negative electrode (cathode) and oxygen gas is formed at the positive electrode (anode).

If 100 g of hydrogen gas is formed in the electrolysis of dilute sulfuric acid, what mass of oxygen gas is also formed?

(A_r values: H = 1; O = 16)

A 50 g

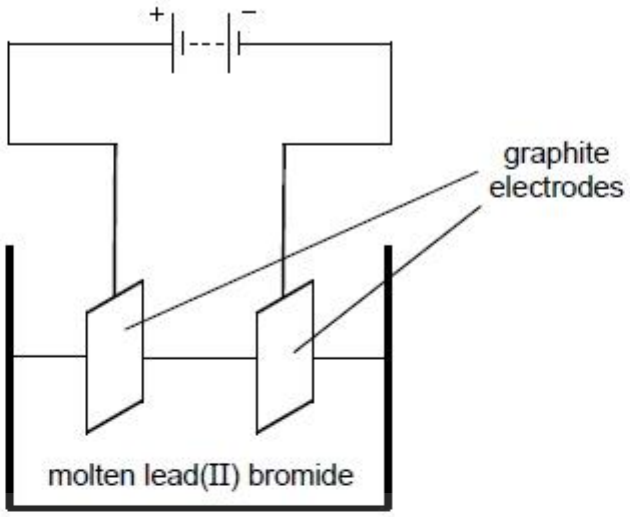
B 100 g

C 200 g

D 800 g

E 1600 g

54 The diagram shows the electrolysis of molten lead(II) bromide, $PbBr_2$, using graphite electrodes to separate the compound into its elements.



Which of the following statements about this electrolysis is/are correct?

1 Lead is formed at the negative electrode.

2 Electrons flow through the external circuit away from the positive electrode towards the negative electrode.

3 Bromine molecules and lead are produced in a 2 : 1 molar ratio.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

c) Determine the oxidation state of the metal atom or atoms in the following species.

(i) MnO_4^{2-}

[1 mark]

Answer: .....

.....

(ii) $K_2Cr_2O_7$

[2 marks]

Answer: .....

.....

.....

.....

d) Write a balanced chemical equation in which Fe^{2+} is oxidised to Fe^{3+} by MnO_4^- in an **acidic aqueous solution** and in which the Mn is reduced to a species with oxidation state +2. Your equation must balance for both atoms and charge, and you may **not** use free electrons (e^-) to achieve this.

[4 marks]

Answer: .....

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39 What is the overall process that takes place at the cathode (negative electrode) in the electrolysis of dilute aqueous sodium sulfate?

A $2H^+ + 2e^- \rightarrow H_2$

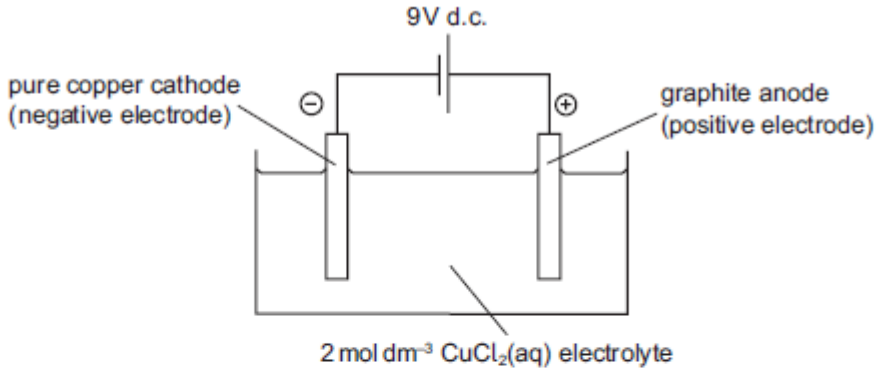
B $2O^{2-} \rightarrow O_2 + 4e^-$

C $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$

D $Na^+ + e^- \rightarrow Na$

E $SO_4^{2-} \rightarrow SO_2 + O_2 + 2e^-$

45 Consider this electrochemical cell containing an aqueous copper(II) chloride electrolyte:



Which row in the following table identifies the reactions occurring at the electrodes?

	cathode (negative electrode)	*anode (positive electrode)*
A	$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$
B	$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$	$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
C	$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$	$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
D	$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$
E	$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$	$2OH^-(aq) \rightarrow H_2(g) + O_2(g) + 2e^-$

50 Consider the following two electrolytic processes:

electrolysis of molten lead(II) chloride

electrolysis of brine (sodium chloride solution)

Which of the following statements is/are correct?

1 In both processes, reduction takes place at the negative electrode.

2 If 20.0 g of product is formed at the negative electrode in each process, then both processes produce the same volume of chlorine gas, measured at room temperature and pressure.

3 In both processes, a metal is produced at the negative electrode.

(A_r values: Cl = 35.5; H = 1.00; Na = 23.0; Pb = 207. Assume that one mole of gas occupies 24.0 dm^3 at room temperature and pressure.)

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

38 When concentrated aqueous sodium chloride solution is electrolysed using inert electrodes a reaction occurs at each electrode.

Which is the correct combination of elements actually produced at the electrodes in this electrolysis?

A positive electrode = chlorine; negative electrode = hydrogen

B positive electrode = chlorine; negative electrode = sodium

C positive electrode = oxygen; negative electrode = hydrogen

D positive electrode = oxygen; negative electrode = sodium

E positive electrode = sodium; negative electrode = chlorine

38 Solid titanium oxide does not conduct electricity and cannot be electrolysed.

When molten, titanium oxide is a conductor and can be electrolysed.

During electrolysis 7.2 g of titanium are formed for every 3.6 dm^3 of oxygen at room temperature and pressure.

Which of the following statements, if any, are correct?

1 After electrolysis, the titanium atoms produced have a noble gas electron configuration.

2 When molten, titanium oxide electrons are delocalised and so they move to carry the charge.

3 The empirical formula of titanium oxide is TiO_2.

(A_r: Ti = 48; molar gas volume = 24 dm^3 at room temperature and pressure)

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2, and 3

39 In which, if any, of the following reactions are covalent bonds both broken and formed?

1 burning sodium in oxygen

2 electrolysis of aqueous sodium chloride

3 displacement of iron from iron oxide by heating with aluminium powder

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2

F 1 and 3

G 2 and 3

H 1, 2 and 3

47 During the electrolysis of a saturated solution of sodium chloride, 2.4 dm^3 of hydrogen gas was collected in time *t* at one of the electrodes.

Assuming no products dissolve, which row in the table correctly gives the mass or volume of the given product collected at the given electrode in time *t*?

(A_r: Na = 23; Cl = 35.5; H = 1, 1 mole of gas occupies 24 dm^3 at room temperature and pressure)

	mass or volume	*product*	*electrode*
A	0.1 g	hydrogen	negative
B	2.3 g	sodium	negative
C	2.4 dm^3	chlorine	positive
D	2.4 dm^3	chlorine	negative
E	2.4 dm^3	oxygen	positive
F	3.55 g	chlorine	positive
G	1.2 dm^3	oxygen	negative

53 During electrolysis of an aqueous solution of sodium sulfate the half equations for the electrode reactions are:

Anode (positive electrode): $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

Cathode (negative electrode): $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

Which of the following deductions, if any, can be made from these equations?

1 The ratio by moles of hydrogen to oxygen produced at the electrodes is 1:1.

2 The sodium sulfate solution will become more concentrated as the electrolysis proceeds.

3 The whole solution will become acidic due to formation of H^+ ions at the anode.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

A Level Topic # **24 Q# 262/**
A Level Topic # **24 Q# 263/**

20 Ethanoic acid, ethanol and water were added to a reaction vessel and a quantity of concentrated sulfuric acid was added. The reaction mixture was then heated and an ester (ethyl ethanoate) and water were formed in equilibrium with the reactants.

$$C_2H_5OH(l) + CH_3COOH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$$

120 g of ethanoic acid and 92 g of ethanol were used and the mass of water present at the start of the experiment was 18 g. Assume that there is no change in volume.

At the temperature of the reaction, the equilibrium constant K_c is 2.00.

What is the mass of the ester present in the mixture at equilibrium?

(M_r values: ethanoic acid = 60; ethanol = 46; water = 18; ethyl ethanoate = 88)

A 1.00 g

B 53.0 g

C 88.0 g

D 103 g

E 106 g

F 176 g

G 209 g

H 215 g

48 50 cm^3 of 0.100 mol dm^{-3} hydrochloric acid has a pH of 1.0.

What is the pH of the mixture formed when 450 cm^3 of 0.010 mol dm^{-3} calcium hydroxide solution is added?

A pH = 1.0

B 1.0 < pH < 2.0

C pH = 2.0

D 2.0 < pH < 7.0

E pH = 7.0

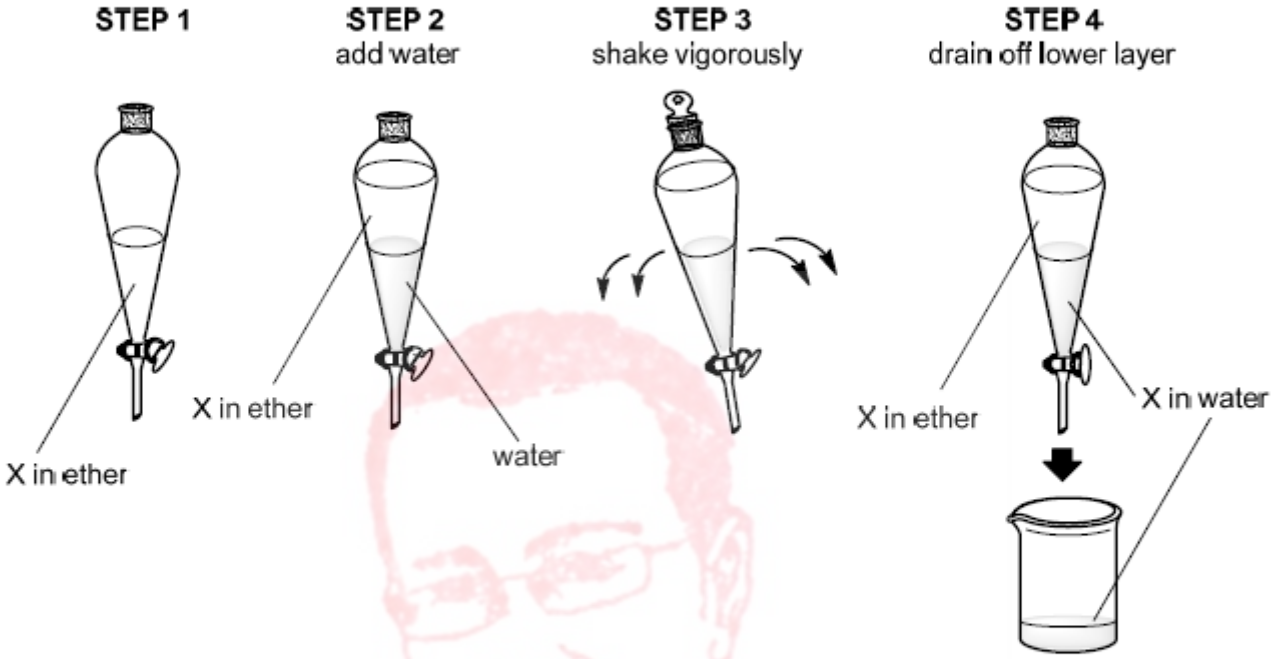
F pH > 7.0

28 Consider the distribution of a solute X between two immiscible solvents: water and ether.

$$X(aq) \rightleftharpoons X(ether)$$

The equilibrium constant, K_c, is 0.15 at 25 °C.

50 cm^3 of a solution of X in ether at 25 °C contains 21.5 g of X. 100 cm^3 of water is added, shaken with the ether solution and allowed to reach equilibrium at 25 °C.



What is the maximum mass of X that can be transferred into the aqueous layer?

A 4.96 g

B 14.3 g

C 18.7 g

D 20.0 g

E 20.5 g

35 Sodium hydrogencarbonate, $NaHCO_3$, and sodium carbonate are both used as antacids. They react with hydrochloric acid in the stomach to form the same products.

The contents of a person's stomach has a pH of 1.0, which is a concentration of $0.1\,mol\,dm^{-3}$ HCl. The stomach contained $80\,cm^3$ of aqueous solution when the pH was measured.

Which of the following amounts of sodium hydrogencarbonate would bring the stomach contents into the normal range of pH 2.0-3.0?

(A_r values: H = 1; C = 12; O = 16; Na = 23)

A 0.0038 mol

B 0.0075 mol

C 0.0080 mol

D 0.016 mol

E 0.095 mol

54 Hydrochloric acid, sulfuric acid and phosphoric(V) acid are inorganic acids.

Phosphoric(V) acid, H_3PO_4, ionises in water in the following series of reactions:

$$H_3PO_4 \rightleftharpoons H^+ + H_2PO_4^-$$

$$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$$

$$HPO_4^{2-} \rightleftharpoons H^+ + PO_4^{3-}$$

0.1 mol dm^{-3} hydrochloric acid has a pH of 1.0 at room temperature.

Which of the following statements about these acids is/are correct?

1 The pH of 0.1 mol dm^{-3} sulfuric acid is greater than 1.0 at room temperature.

2 $H_2PO_4^-$ can act as an acid or as a base.

3 30 cm^3 of calcium hydroxide solution exactly neutralises 20 cm^3 phosphoric(V) acid solution when both solutions are the same concentration.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

Question C2

Trifluoroethanoic acid, TFEA, is a carboxylic acid often used in organic chemistry and has the formula CF_3COOH. The density of TFEA is 1.489 g cm^{-3}.

An aqueous solution of TFEA is made up by mixing 0.0700 mol of the pure acid with water and making the solution up to 100.0 cm^3.

b) Calculate the volume of pure TFEA needed to make the solution.

[3 marks]

Answer: .....

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c) Give an equation for the ionisation of TFEA in water.

[1 mark]

Answer: .....

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d) Give an expression for the equilibrium constant for the ionisation of TFEA in water.

[2 marks]

Answer: .....

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e) Given that the measured concentration of H^+ ions is 0.4119 mol dm^{-3}, calculate the value of the equilibrium constant. You may ignore the self-dissociation of water.

[3 marks]

Answer: .....

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Question 4

a) Arsenic oxide As_2O_3 is prepared on an industrial scale by roasting arsenic-containing ores such as arsenopyrite, FeAsS, in air. The other products formed are iron(III) oxide and sulfur dioxide.

b) As_2O_3 is moderately soluble in water; one dm^3 of a saturated solution at 25 °C contains 20.6 g. When dissolved in water, the oxide reacts to form arsenous acid, H_3AsO_3.

d) Diluted hydrochloric acid is also sold as a homeopathic medicine. The pH of a solution may be calculated using the following equation:

$$pH = -\log_{10} [H^+]$$

where $[H^+]$ is the total concentration of hydrogen ions, in mol dm^{-3}, in aqueous solution. Rearranging this equation allows us to calculate the total concentration of hydrogen ions from the pH of the solution:

$$[H^+] = 10^{-pH}$$

(i) What is the pH of pure water at room temperature? Calculate $[H^+]$ for pure water. **[3 marks]**

Answer: .....

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(ii) Assuming the original stock solution before dilution has a concentration of 1.0 mol dm^{-3}, what is the concentration of HCl and pH obtained by the following dilutions of the stock solution: **1)** dilution by a factor of 10^2; **2)** dilution by a factor of 10^8; **3)** dilution by a factor of 10^{10}. **[3 marks]**

Answer: .....

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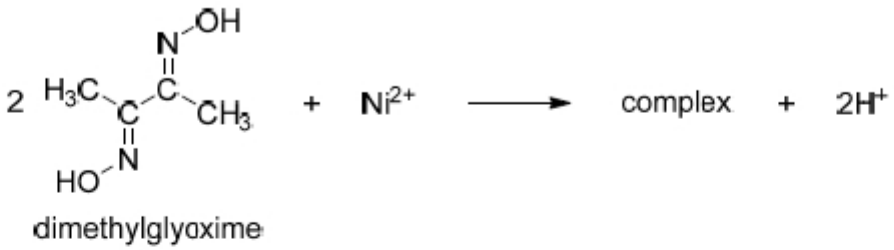
c) Dimethylglyoxime reacts with Ni^{2+} ions in aqueous solution under mildly basic conditions to give a complex which is an insoluble red precipitate. The reaction involves two molecules of dimethylglyoxime and also results in the production of two H^+ ions.



dimethylglyoxime

Assuming that the above equation is balanced, determine the **molecular formula** of the complex and its relative molecular mass; a structural formula is **not** required.

(Relative atomic mass data is given in the Periodic Table on page 14.)

[4 marks]

Answer: .....

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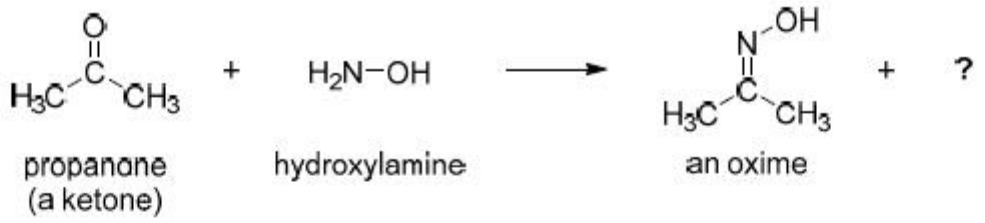
Question C1

a) Ketones react with hydroxylamine, NH_2OH, to give oximes. An example of such a reaction involving the ketone propanone is shown below:



propanone (a ketone) hydroxylamine an oxime

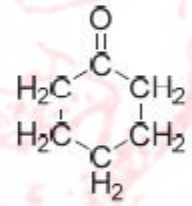
(i) In addition to the oxime, this reaction produces a second product. Suggest what this molecule might be.

[1 mark]

Answer: .....

.....

(ii) Draw the structure of the oxime that you would expect to be formed from the reaction of the ketone cyclohexanone with hydroxylamine.

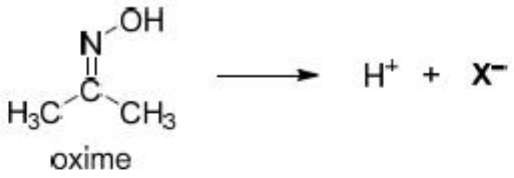


cyclohexanone

[2 marks]

Answer:

(iii) Oximes are weakly acidic. For the oxime below, explain which hydrogen atom will be the most acidic and draw the structure of the resulting anion X^-.



oxime

[3 marks]

Answer: .....

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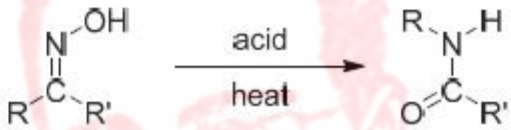
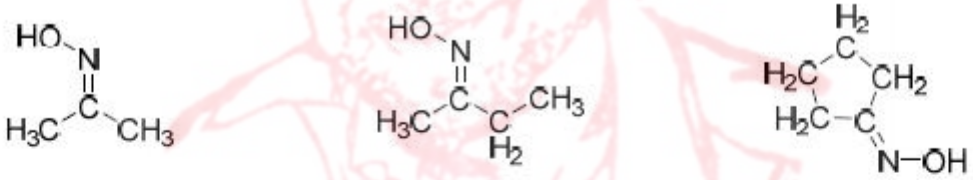
b) Under acidic conditions, oximes undergo the following rearrangement reaction (note carefully that there are two different groups R and R').



Give the analogous structures into which each of the following oximes rearrange under the same conditions.



[4 marks]

Answer:

A Level Topic # 34 **Q# 273/ Cambridge/2020/Section 1 www.SmashingScience.org**

49 A paper chromatogram is set up with an orange food colouring spotted on the baseline.

Ten minutes after the start, the solvent front has moved 15.0 cm up the paper from the baseline and a yellow spot is 12.0 cm above the baseline.

Five minutes later, the solvent front has moved up a further 10.0 cm.

How far from the baseline will the yellow spot be 15 minutes after the start?

A 8.0 cm

B 12.0 cm

C 15.0 cm

D 20.0 cm

E 22.0 cm

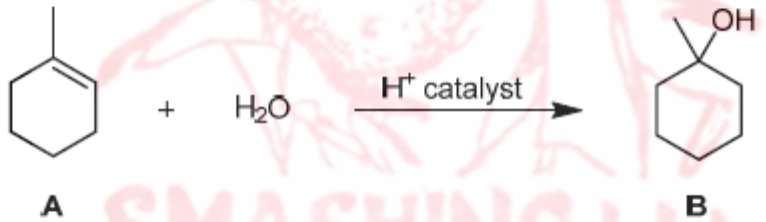
F 25.0 cm

G 31.3 cm

A Level Topic # 35 **Q# 274/ Cambridge/2019/Section 2/ www.SmashingScience.org**

A mixture of TFEA and trifluoroethanoic anhydride, $CF_3COOCOCF_3$, was used as the solvent system in a series of experiments to determine the standard enthalpy changes of hydration of various alkenes.

1-methylcyclohexene, **A**, may be hydrated in an acid-catalysed reaction as shown below:



f) How may this reaction be classified? Choose from: *addition*, *elimination*, *substitution*, *oxidation*, *addition polymerisation*.

[1 mark]

Answer: .....

g) Draw the structure of the intermediate initially formed when the H^+ catalyst reacts with alkene **A**.

[1 mark]

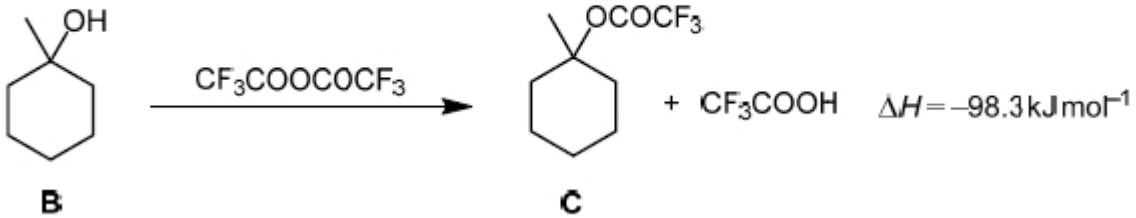
Answer:

h) The same product **B** is formed when an alkene isomer of **A** is treated under identical conditions. Suggest a structure for this isomer.

[1 mark]

Answer:

In a mixture of TFEA and trifluoroethanoic anhydride, **B** reacts with the trifluoroethanoic anhydride to form **C** and TFEA as shown below. The standard enthalpy change for this reaction is $-98.3\ kJ\ mol^{-1}$.



i) Draw the structure of trifluoroethanoic anhydride.

[1 mark]

Answer:

A Level Topic # 36 **Q# 275/ Cambridge/2022sp/Section 2/ www.SmashingScience.org**

18 Compound P, with molecular formula C_5H_{10}, reacts with hydrogen bromide in an addition reaction to form compound Q as the major product.

Q undergoes a substitution reaction with aqueous sodium hydroxide to form compound R.

After R is completely oxidised using acidified potassium dichromate(VI), the resulting product does **not** react with aqueous sodium carbonate.

R undergoes an elimination reaction to form a mixture of products: P and S.

S has no stereoisomers.

What is compound P?

A pent-1-ene

B pent-2-ene

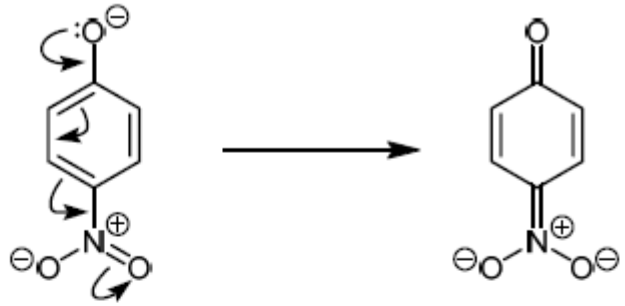
C 2-methylbut-1-ene

D 2-methylbut-2-ene

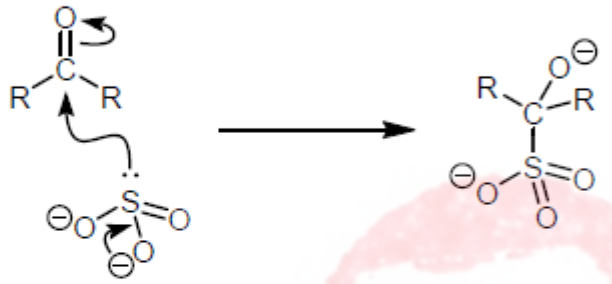
E 3-methylbut-1-ene

25 Which of the following does **not** give the species shown?

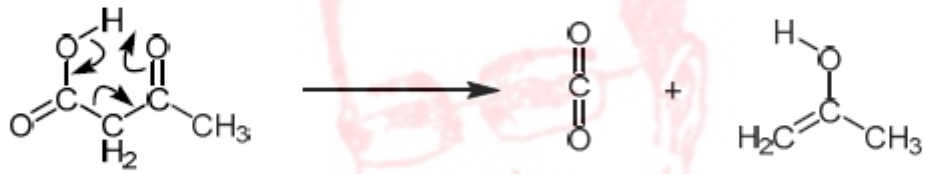
A



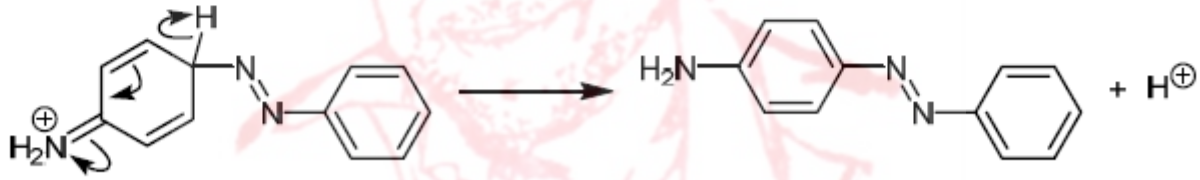
B



C



D



E

26 0.4 mol of a halogenoalkane reacted completely with hot, ethanolic potassium hydroxide to give 28 g of a single organic product X in 100% yield.

What percentage of all of the structural isomers with both the same functional group and molecular formula as X would show geometric (*E*/*Z*) isomerism?

(A_r values: H = 1; C = 12)

A 17%

B 20%

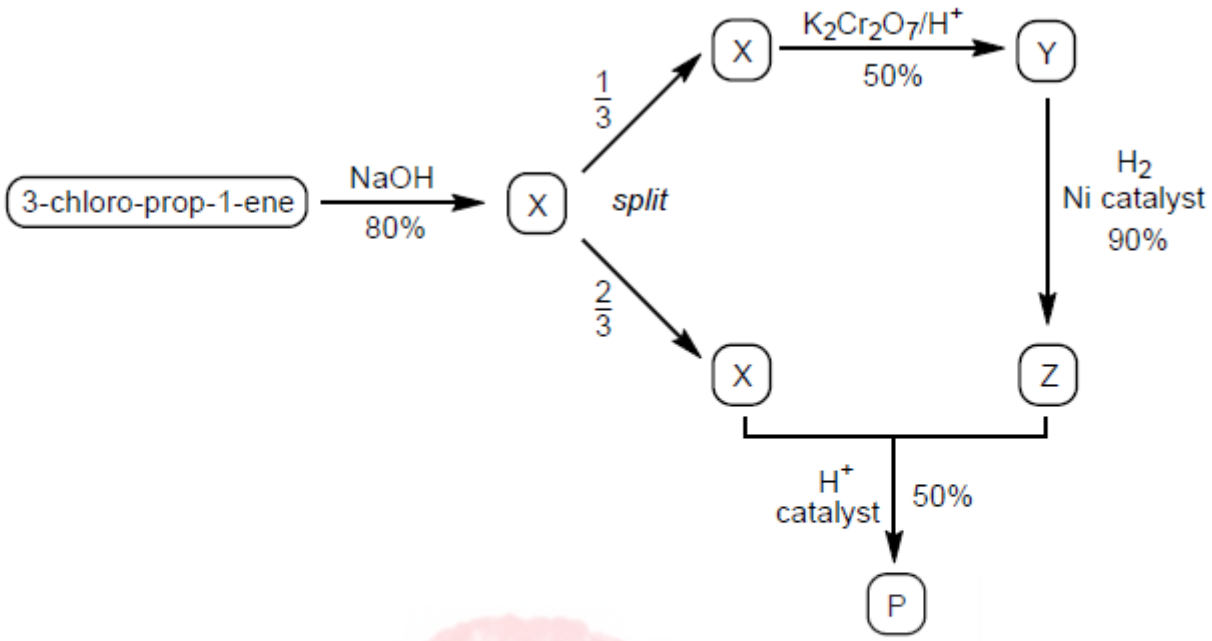
C 25%

D 33%

E 40%

F 50%

29



5.0 mol of 3-chloro-prop-1-ene (M_r = 76.5) was reacted with excess sodium hydroxide to form a single product X in 80% yield.

One third of compound X was heated with excess acidified potassium dichromate(VI) under reflux to form a single product Y in 50% yield.

All of compound Y was reacted with hydrogen gas at high temperature in the presence of nickel to form a single product Z in 90% yield.

The remaining quantity of compound X was reacted with all of compound Z in the presence of an acid catalyst to form product P in 50% yield.

What is the maximum mass of product P that could be produced from this synthesis?

(A_r values: H = 1; C = 12; O = 16; Cl = 35.5)

A 2.74 g

B 5.48 g

C 23.0 g

D 34.2 g

E 114 g

F 123 g

G 152 g

36 X is a **di**carboxylic acid. When in aqueous solution, 2.36 g of X reacts with excess sodium carbonate to produce 480 cm^3 of carbon dioxide, measured at room temperature and pressure. Assume that no gas dissolves in the water present.

Y is a liquid organic compound containing only one functional group. 1 mol of Y reacts exactly with 1 mol of sodium, giving off a gas that pops with a lighted splint. Aqueous Y does not change the colour of blue or red litmus papers.

When 50.0 cm^3 of gaseous Y is combusted in excess oxygen, 150 cm^3 of carbon dioxide and 200 cm^3 of water vapour are the only products formed. All volumes are measured at the same temperature and pressure.

When heated in the presence of concentrated sulfuric acid, 1 mol of X reacts completely with 2 mol of Y to give 1 mol of organic product Z. Water is also produced in the reaction.

What is the relative molar mass of Z?

(A_r values: H = 1; C = 12; O = 16. Assume that one mole of gas occupies 24 dm^3 at room temperature and pressure.)

A 101

B 160

C 166

D 170

E 202

F 220

38 Analysis of hydrocarbon P showed it to contain 0.60 g of carbon and 0.10 g of hydrogen, and to have a relative molecular mass of 70.

P reacts with hydrogen bromide to form a mixture of Q and R. However, the main product was Q.

Q reacts with warm, aqueous sodium hydroxide to form S.

S reacts with warm, acidified potassium dichromate(VI) to form T. T does not produce a silver mirror with Tollens' reagent and does not produce bubbles when sodium carbonate is added.

S undergoes dehydration on reaction with hot, concentrated sulfuric acid to form the original hydrocarbon P and a new compound U. Both P and U do not have stereoisomers.

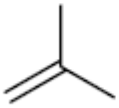
What is the structure of compound U?

(A_r values: H = 1; C = 12)

A

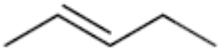
B

C

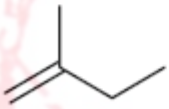


D

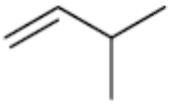
E



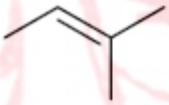
F



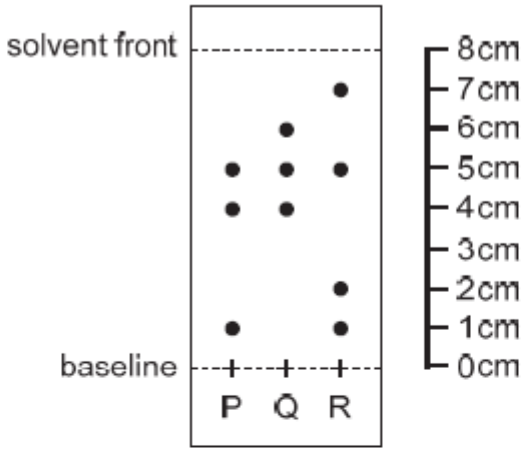
G



H



51 Three mixtures (P, Q and R) of amino acids were separated using paper chromatography.



The test was repeated with the same mixtures, paper and solvent but this time the distance travelled by the common component of the mixtures was 7.5 cm.

How far did the most mobile component of mixture Q travel in the second test?

A 6.0 cm

B 8.5 cm

C 9.0 cm

D 9.6 cm

E 10.5 cm

F 12.0 cm

49 A paper chromatogram is set up with an orange food colouring spotted on the baseline.

Ten minutes after the start, the solvent front has moved 15.0 cm up the paper from the baseline and a yellow spot is 12.0 cm above the baseline.

Five minutes later, the solvent front has moved up a further 10.0 cm.

How far from the baseline will the yellow spot be 15 minutes after the start?

A 8.0 cm

B 12.0 cm

C 15.0 cm

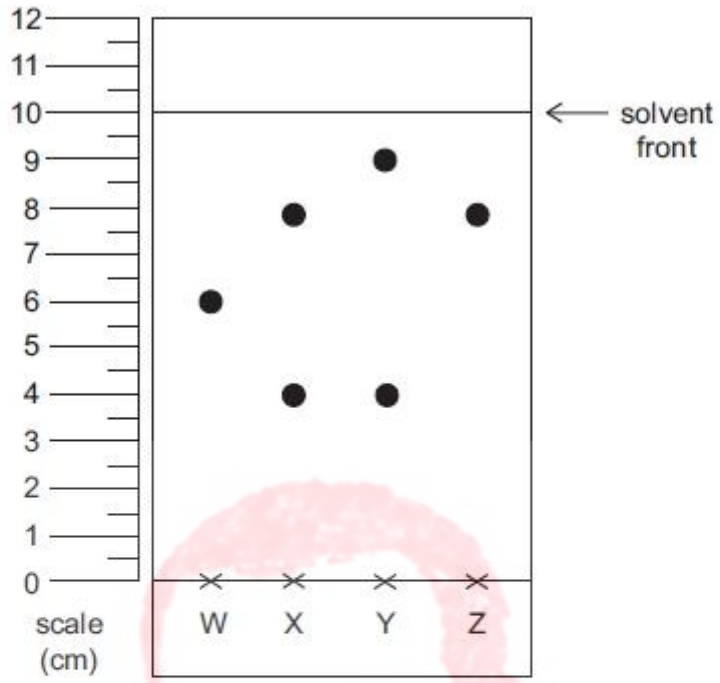
D 20.0 cm

E 22.0 cm

F 25.0 cm

G 31.3 cm

39 Four samples, labelled W, X, Y and Z, were investigated using paper chromatography with a solvent that caused any mixtures present to be fully separated. The results are shown in the chromatogram.



What is the R_f value of the spot with the strongest attraction to the mobile phase relative to the stationary phase **and** that is from a sample containing only one substance?

A 0.50

B 0.60

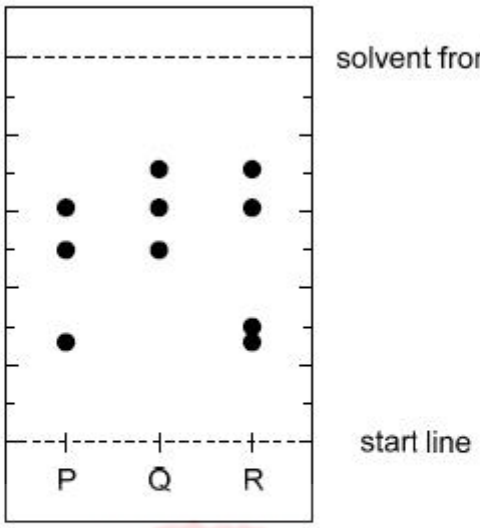
C 0.67

D 0.75

E 0.80

F 0.90

49 Paper chromatography was used to separate three mixtures of amino acids. The mixtures were labelled P, Q and R.



Each mixture contains some of the five amino acids in the following table. The R_f values were measured for each amino acid with the solvent used to produce the chromatogram.

amino acid	*R_f value*
asparagine	0.50
glutamic acid	0.30
glycine	0.26
leucine	0.71
valine	0.61

Which of the following statements is/are correct?

1 Mixture P contains valine and glycine.

2 Leucine is found in all three mixtures.

3 Glutamic acid is the least mobile amino acid with this solvent.

4 Mixtures P and Q both contain asparagine.

A 1 and 2 only

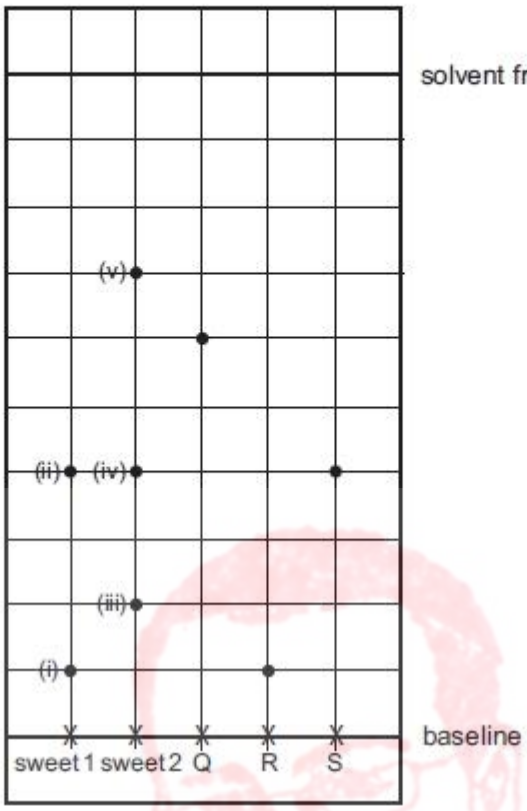
B 1 and 4 only

C 2 and 3 only

D 3 only

E 4 only

41 Study the chromatogram below showing the spots obtained, labelled (i) to (v), from two sweets and pure samples of the food additives, labelled Q, R and S.



Which of the following statements about the chromatogram is/are correct?

1 Both sweet 1 and 2 contain additives R and S.

2 The R_f value for spot (iv) is half that for spot (iii).

3 The R_f value for spot (v) is 0.7.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

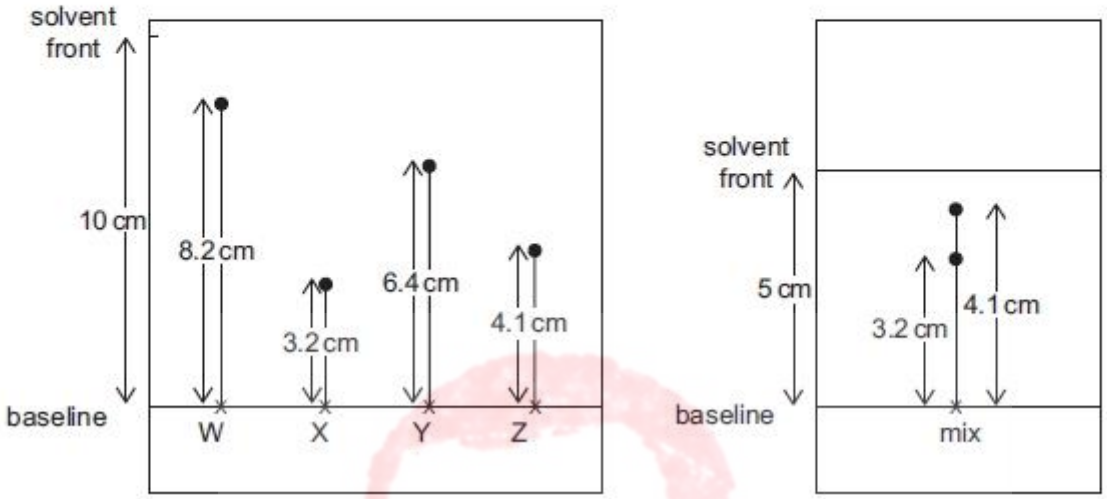
G 2 and 3 only

H 1, 2 and 3

43 A chromatogram was produced for 4 separate dyes (W, X, Y and Z) using filter paper and a water solvent.

A second chromatogram was produced using a mixture of two of the dyes, again using filter paper and a water solvent:

[diagram not to scale]



Which of the following statements, if any, are correct?

1 The concentration of dye W must be twice the concentration of dye Z.

2 The mobile phase is the filter paper.

3 The mixture in the second chromatogram contained dyes W and Y.

A none of them

B 1 only

C 2 only

D 3 only

E 1 and 2 only

F 1 and 3 only

G 2 and 3 only

H 1, 2 and 3

Mark Scheme Uni NSAA Section 1 AND 2 16sp to 22 2023

Q# 1/ Cambridge/2022/Section 2/ www.SmashingScience.org

Q41	E

Q# 2/ Cambridge/2022/Section 1 www.SmashingScience.org

Q41	E

Q# 3/ Cambridge/2021/Section 1 www.SmashingScience.org

Q47	F

Q# 4/ Cambridge/2021/Section 1 www.SmashingScience.org

Q59	E

Q# 5/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q43	F

Q# 6/ Cambridge/2020/Section 1 www.SmashingScience.org

Q43	F	CHEM

Q# 7/ Cambridge/2020/Section 1 www.SmashingScience.org

Q52	E	CHEM

Q# 8/ Cambridge/2019/Section 1 www.SmashingScience.org

45	H

Q# 10/

Q50	G

Q# 11/ Cambridge/2022/Section 1 www.SmashingScience.org

Q53	D

Q# 12/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q32	G

Q# 13/ Cambridge/2021/Section 1 www.SmashingScience.org

Q42	C

Q# 14/ Cambridge/2021/Section 1 www.SmashingScience.org

Q43	B

Q# 15/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q56	E

Q# 16/ Cambridge/2020/Section 1 www.SmashingScience.org

Q56	E	CHEM

Q# 17/ Cambridge/2019/Section 1 www.SmashingScience.org

42	F

Q# 18/ Cambridge/2018/Section 1 www.SmashingScience.org

37	C

Q# 19/ Cambridge/2017/Section 1 www.SmashingScience.org

37	F

Q# 20/ Cambridge/2017/Section 1 www.SmashingScience.org

54	D

Q# 21/ Cambridge/2016/Section 1 www.SmashingScience.org

37	D

Q# 22/ Cambridge/2022sp/Section 2/ www.SmashingScience.org

14 E

14 The answer is option **E**.

From the information provided in the question the formulae in the chemical equation can be deduced to be:

$$?SO_3 + ?Cl_2 + ?SCl_2 \rightarrow ?SOCl_2$$

Balancing: $$SO_3 + Cl_2 + 2SCl_2 \rightarrow 3SOCl_2$$

Number of moles Cl_2 gas $= \frac{2}{24} = \frac{1}{12}$

Mole ratio $Cl_2 : SOCl_2$ $= 1:3$

Number of moles of $SOCl_2$ $= \frac{1}{12} \times 3 = 0.25\,\text{mol}$

$SOCl_2$ is collected in water, where it reacts. It produces HCl, which will dissolve to form hydrochloric acid, and another gaseous product, which can be deduced to be sulfur dioxide:

$$SOCl_2 + H_2O \rightarrow 2HCl + SO_2$$

Mole ratio $SOCl_2 : HCl$ $= 1:2$

Number of moles of HCl $= 0.25 \times 2 = 0.50\,\text{mol}$

Concentration of HCl $= \frac{\text{number of moles}}{\text{volume}} = \frac{0.50}{\left(\frac{200}{1000}\right)} = 2.50\,\text{mol dm}^{-3}$

Q# 23/ Cambridge/2022sp/Section 2/ www.SmashingScience.org

17 E

17 The answer is option **E**.

Putting the known coefficients into the equation:

$$As_2O_3(s) + 6Zn(s) + H^+(aq) \rightarrow 6Zn^{2+}(aq) + 2X(g) + H_2O(l)$$

Six zinc atoms each increase their oxidation state by 2 in being oxidised to zinc ions. This gives a total increase in oxidation state of 12.

To balance this, the two arsenics in As_2O_3 must collectively reduce their oxidation states by 12 (i.e. each arsenic in As_2O_3 must reduce its oxidation state by 6).

The oxidation state of arsenic in As_2O_3 is +3 (because the oxidation state of the oxygen is –2). Hence each of the two arsenics in X must have an oxidation state of –3.

The only possible arsenic-containing product in this reaction that gives arsenic an oxidation state of –3 is AsH_3.

The balanced equation for the reaction is therefore:

$$As_2O_3(s) + 6Zn(s) + 12H^+(aq) \rightarrow 6Zn^{2+}(aq) + 2AsH_3(g) + 3H_2O(l)$$

The M_r of As_2O_3 is 198 and the M_r of AsH_3 is 78.

From the stoichiometry of the reaction, 198 g of As_2O_3 would produce 156 g of AsH_3.

Hence, 1.98 g of As_2O_3 would produce 1.56 g of AsH_3.

Q# 24/ Cambridge/2022/Section 2/ www.SmashingScience.org

Q53	D

Q# 25/ Cambridge/2022/Section 2/ www.SmashingScience.org

Q58	A

Q# 26/ Cambridge/2022/Section 1 www.SmashingScience.org

Q55	D

Q# 27/ Cambridge/2022/Section 1 www.SmashingScience.org

Q58	A

Q# 28/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q21	C

Q# 29/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q24	F

Q# 30/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q30	E

Q# 31/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q37	D

Q# 32/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q40	C

Q# 33/ Cambridge/2021/Section 1 www.SmashingScience.org

Q50	E

Q# 34/ Cambridge/2021/Section 1 www.SmashingScience.org

Q52	C

Q# 35/ Cambridge/2020SP/Section 2/ www.SmashingScience.org

14 E

Q# 36/ Cambridge/2020SP/Section 2/ www.SmashingScience.org

15 A

Q# 37/ Cambridge/2020SP/Section 2/ www.SmashingScience.org

17 E

Q# 38/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

44 A

44

The answer is option **A**.

The reaction is stated to go to completion.

At the start of the reaction there is a concentration of A of 1.2 mol dm^{-3}. The equation gives the ratio of A : Z as 2 : 1. This means that for every unit of A that is reacted, only 0.5 as much Z is produced.

In a complete reaction, all of A will be used up and the final concentration of Z will be 0.6 mol dm^{-3}, so graph 1 must be correct.

As the chemical A is reacted, Z is produced. Graph 2 shows that an equilibrium state has been reached with the concentration of A being twice that of Z; this is incorrect.

Graph 3 shows that an equilibrium state has been reached with equal concentrations of A and Z; this is incorrect.

Q# 39/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

45 B

45

The answer is option **B**.

One method for solving the problem would be as follows:

The oxide ion has a charge of -2, O^{2-}.

A compound formed from Fe^{3+} and O^{2-} ions must have the formula Fe_2O_3.

A compound formed from Fe^{2+} and O^{2-} ions must have the formula FeO.

A 1 : 1 mixture of these compounds would give a compound of formula Fe_3O_4 (Fe_2O_3 + FeO).

So the molar ratio Fe^{3+} : Fe^{2+} must be 2 : 1, making Fe^{2+} $\frac{1}{3}$ of the iron ion total.

Q# 40/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

49 D

49

The answer is option **D**.

1 mole of H_2O has a mass of $(2\times 1)+16 = 18\,g$

The volume of 1 mole of a gas at room temperature and pressure is $24\,dm^3$

6.00 g of H_2O is $\frac{6}{18} = \frac{1}{3}$ mol, and therefore occupies a volume of $\frac{24}{3} = 8\,dm^3$

$8\,dm^3 = 8000\,cm^3$

Q# 41/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

50 E

50

The answer is option **E**.

There are several methods that will give the correct answer, of which one is shown below:

	I	O
number of moles:	$\frac{63.5}{127} = 0.5$	$\frac{20.0}{16} = 1.25$
ratio ($\div 0.5$)	1	2.5
smallest whole number ratio ($\times 2$)	2	5

Therefore the empirical formula is I_2O_5.

Q# 42/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

52 C

52

The answer is option **C**.

This question is about identifying which possible isotopes can give rise to CH_2BrCl with $M_r = 128$, and the proportion of these isotopes that exist, to identify which isotope combinations give $M_r = 128$ and those that do not.

The combined total mass of bromine and chlorine (removing CH_2) must total $128 - 14 = 114$

The only combination of isotopes with this total mass is ^{79}Br combined with ^{35}Cl. As these are the isotopes with lowest mass for each element, any other possibilities would result in a higher M_r for the compound.

The fraction occurring is directly related to probability. We want the probability that $Br = {}^{79}Br$ AND $Cl = {}^{35}Cl$, in CH_2BrCl and these events are independent of each other.

^{35}Cl is three times as common as ^{37}Cl, and the question states that there are only two isotopes to be considered (3 : 1), so the relative frequency of ^{35}Cl is $\frac{3}{4}$, and for ^{37}Cl it is $\frac{1}{4}$. We can treat these as probabilities.

For bromine, the relative frequency of ^{79}Br is $\frac{1}{2}$, and it is the same for ^{81}Br.

Hence $P(^{79}Br \text{ AND } ^{35}Cl) = P(Br = {}^{79}Br) \times P(Cl = {}^{35}Cl) = \frac{1}{2} \times \frac{3}{4} = \frac{3}{8}$

Q# 43/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

54 D

54

The answer is option **D**.

In this question, stage 1 can be ignored.

In stage 2, the stoichiometry of the equation shows that 1 mole of C will produce 2 moles of CO.

12 g of C (A_r 12) is 1 mole

M_r of CO is $12 + 16 = 28$, so 2 moles of CO is $28 \times 2 = 56$ g

In stage 3, the stoichiometry of the equation shows that 3 moles of CO will produce 3 moles of CO_2, i.e. a 1 : 1 molar ratio.

56 g (2 moles) of CO will make 2 moles CO_2

M_r of CO_2 is $12 + (16 \times 2) = 44$, so 2 moles of CO_2 is $44 \times 2 = 88$ g

Q# 44/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

56 E

56

The answer is option **E**.

The chemical equation for the reaction is: $NaOH + HCl \rightarrow NaCl + H_2O$

Molar ratio is 1 NaOH : 1 HCl

$$\text{Number of moles of HCl} = \frac{\text{vol. in cm}^3}{1000} \times \text{conc.} = \frac{50.0}{1000} \times 0.5 = 0.025$$

Therefore, the number of moles of NaOH is also 0.025

A_r of NaOH is 23 + 1 + 16 = 40, so 1 mole of NaOH has a mass of 40 g

In the question, the number of moles of NaOH present = $0.025 \times 40 = 1.0\,g$

$$\text{Percentage purity} = \frac{1.0}{1.20} \times 100 = 83.3\%$$

Q# 45/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

57 C

57

The answer is option **C**.

Various approaches can be used to calculate the correct answer, of which one is shown below.

$$\text{Number of moles } H_2SO_4 \text{ used} = \frac{12.5}{1000} \times 2.0 = 0.025$$

Molar ratio in the reaction is 2 XOH : 1 H_2SO_4

So, the number of moles of XOH present = $0.025 \times 2 = 0.05$

$$\text{Number of moles} = \frac{\text{mass in g}}{M_r}, \text{ so } 0.05 = \frac{2.8}{M_r}$$

$$\text{Rearranging, } M_r = \frac{2.8}{0.05} = \frac{28}{0.05} = 56$$

M_r of XOH = $A_r(X) + 16 + 1 = 56$

$A_r(X) = 39$

Q# 46/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

58 D

58

The answer is option **D**.

The number of moles of each element on each side of the equation is:

	H	N	O
left-hand side	r	r	$3r$
right-hand side	$2s$	$2 + t$	$6 + s + 2t$

These numbers must balance for each element:

For H, $r = 2s$

For N, $r = 2 + t$

For O, $3r = 6 + s + 2t$

Substituting $r = 2s$ into $3r = 6 + s + 2t$, we get $3 \times (2 + t) = 6 + s + 2t$

Rearranging: $6 + 3t = 6 + s + 2t$, therefore $t = s$

Moles of H and N are equal (r), so $2s = 2 + t$

Substituting $t = s$ into this, we get $2s = 2 + s$ and therefore $s = 2$

It follows that $t = 2$ and $r = 4$

Q# 47/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

59 D

59

The answer is option **D**.

The volume of CO_2 gas produced ($105\,cm^3$) is three times that of the alkane vapour ($35\,cm^3$) at the same temperature and pressure.

Using the reacting volumes of gases ratio, the mole ratio of alkane : CO_2 is 1 : 3

As this is complete combustion, all of the carbon atoms in the alkane will form CO_2, so it can be deduced that there are 3 carbon atoms in the alkane molecule.

The general formula of alkanes is C_nH_{2n+2}, so the alkane formula is C_3H_8.

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

Q# 48/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q45	E

Q# 49/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q46	B

Q# 50/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q52	E

Q# 51/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q60	F

Q# 52/ Cambridge/2020/Section 1 www.SmashingScience.org

Q44	B	CHEM

Q# 53/ Cambridge/2020/Section 1 www.SmashingScience.org

Q45	E	CHEM

Q# 54/ Cambridge/2020/Section 1 www.SmashingScience.org

Q46	B	CHEM

Q# 55/ Cambridge/2020/Section 1 www.SmashingScience.org

Q55	C	CHEM

Q# 56/ Cambridge/2020/Section 1 www.SmashingScience.org

Q57	G	CHEM

Q# 57/ Cambridge/2019/Section 2/ www.SmashingScience.org

d) Since only one Te atom present molecule, 3 moles of F2 form 1 mol of gas A. So 1 mol of A must containt 6 mols of F, i.e. A is TeF_6.

e) Octahedral stucture, so F—Te—F must be 90°.

f) Moles of A = 50/24000. Mass of Te = 127.6 x 50/24000 = 0.266 g

g) Density = [127.6+(6x19)]/24000 = 0.01007 g cm^{-3}.

h) Ratio of densities = ratio of molar masses = [(6x19)+127.6]/32 = 7.55

i) 2n – m **[1]**

j) 9.0 g of acid contains 5.0 g of Te. So one mole of Te (127.6 g) would be in 127.6 x 9.0 / 5.0 = 230 g. **[1]**

k) RMM of salt = 127.6 x 18 / 5.0 = 459.

459 – 230 = 39m – m
so m = 6.0
n = [230 -127.6 – 6]/16 = 6
Formulae are H_6TeO_6 and K_6TeO_6. **[2]**

l) moles of acid = 5 / 127.6
moles of KOH needed = 6 x 5 / 127.6
volume needed = 6 x 5 x 1000 / (127.6 x 2) = 117 cm^3. **[2]**

Q# 58/ Cambridge/2019/Section 1 www.SmashingScience.org

43	E

Q# 59/ Cambridge/2019/Section 1 www.SmashingScience.org

47	D

Q# 60/ Cambridge/2019/Section 1 www.SmashingScience.org

48	A

Q# 61/ Cambridge/2019/Section 1 www.SmashingScience.org

52	E

Question C2

a) Write a balanced chemical equation for the reaction between $CO_2(g)$ and $OH^-(aq)$, giving $CO_3^{2-}(aq)$ as one of the products.

[1 mark]

Answer: $CO_2(g) + 2OH^-(aq) \rightarrow CO_3^{2-}(aq) + H_2O(l)$ [1]

Accept: no state symbols

$CO_2 + OH^- \rightarrow CO_3^{2-} + H^+$

↑ but this is incorrect for (b)(ii) and (b)(iii)

b) An organic molecule is known to contain C, H and O only. A sample of mass 0.100 g is carefully burnt in the presence of excess oxygen. The resulting gases are passed over a desiccant (drying agent), and it is observed that the mass of the desiccant increases by 0.0931 g.

After passing through the desiccant the gases are bubbled through 25.0 cm^3 of a solution of 1.00 mol dm^{-3} NaOH. The solution is then titrated against 1.00 mol dm^{-3} HCl, and the end point is found to be when 14.7 cm^3 of the acid has been added.

(i) Calculate the amount in moles of H_2O produced by the combustion.

[2 marks]

Answer: $m_{H_2O} = 0.0931\ g$ [1]

$n_{H_2O} = \frac{0.0931\ g}{16.00 + 2 \times 1.008} = 5.167628774 \times 10^{-3}\ mol \approx 5.17 \times 10^{-3}\ mol$ [1]

(ii) Calculate the amount in moles of CO_2 absorbed by the NaOH solution.

[4 marks]

Answer: $n_{HCl} = 14.7 \times 10^{-3}\ dm^3 \times 1.00\ mol\ dm^{-3}$

$= 14.7 \times 10^{-3}\ mol \approx 0.0147\ mol$ [1]

$n_{OH^-\ titrated} = n_{HCl} = 14.7 \times 10^{-3}\ mol$ [1]

$n_{OH^-\ reacted\ with\ CO_2} = (25.0 \times 10^{-3}\ dm^3 \times 1.00\ mol\ dm^{-3})$

$- 14.7 \times 10^{-3}\ mol$ [1]

$\approx 10.3 \times 10^{-3}\ mol \approx 0.0103\ mol$

$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

$2 : 1$

$n_{CO_2} = 10.3 \times 10^{-3}\ mol \times \frac{1}{2} = 5.15 \times 10^{-3}\ mol$

$\equiv 0.00515\ mol$ [1]

If 1 : 1 ratio in a), accept e.c.f.: $10.3 \times 10^{-3}\ mol$ [1]

(iii) Hence determine the empirical formula of the organic molecule.

[6 marks]

Answer: $n_C = n_{CO_2} = 5.15 \times 10^{-3}$ mol [1]

$n_H = 2 \times n_{H_2O} = 2 \times 5.1676 \times 10^{-3}$ mol $= 10.335 \times 10^{-3}$ mol [1]

Mass of O in sample:

$0.100\,g - (5.15 \times 10^{-3}\,mol \times 12.00\,g\,mol^{-1})$

$- (10.335 \times 10^{-3}\,mol \times 1.008\,g\,mol^{-1}) = 0.02778\,g$ [1]

$\therefore n_O = \frac{0.02778\,g}{16.00\,g\,mol^{-1}} = 1.7364 \times 10^{-3}$ mol [1]

$n_C : n_H : n_O = 3 : 6 : 1$ [1]

Empirical formula: C_3H_6O [1]

Q# 63/ Cambridge/2018/Section 2/ www.SmashingScience.org

d) The reaction between dimethylglyoxime and Ni^{2+} ions can be used to determine the nickel content of alloys by weighing the amount of the red precipitate produced from a known mass of a sample of an alloy.

A sample of mass 1.50 g of an alloy was dissolved in dilute acid and an excess of dimethylglyoxime was then added to the resulting solution. The pH was then adjusted to make the solution mildly alkaline, and this resulted in the formation of a red precipitate. The precipitate was carefully filtered off, dried and then weighed. The mass of the dry precipitate was 0.368 g.

Determine the nickel content of the alloy, expressed as a percentage by mass.

[4 marks]

Answer: $\frac{0.368}{288.922} = 1.2737 \times 10^{-3}$ mol [1]

Amount of Ni: 1.2737×10^{-3} mol [1]

Mass of Ni: 0.07475 g [1]

% Mass of Ni: 4.98356 % [1]

e) Other metal ions, such as Pd^{2+} or Pt^{2+}, also react with dimethylglyoxime to give insoluble precipitates. What effect would the presence of palladium in the alloy have on the value of the nickel content determined using the method in part **d)**?

[2 marks]

Answer: Pd / Pt will precipitate → increase in mass. [1]

Make the Ni (%) look too high = wrong answer for Ni value. [1]

Q# 64/ Cambridge/2018/Section 1 www.SmashingScience.org

47	A

Q# 65/ Cambridge/2018/Section 1 www.SmashingScience.org

51	C

Q# 66/ Cambridge/2018/Section 1 www.SmashingScience.org

52	C

Q# 67/ Cambridge/2018/Section 1 www.SmashingScience.org

53	B

Q# 68/ Cambridge/2017/Section 2/ www.SmashingScience.org

c) When 3.8 g of lithium aluminium hydride is heated to 125 °C, it decomposes to give three substances: 1.8 g of aluminium metal, 2.4 dm^3 of a flammable gas (measured at rtp), and substance **B**.

Determine the formula for substance **B**.

[5 marks]

Answer: 2.4 dm^3 of gas at rtp corresponds to 2.4/24.0 = 0.10 mol of the gas .....

.....$M_r(LiAlH_4) = 6.94 + 26.98 + 4 \times 1.008 = 37.952$ g mol^{-1} .....

..... 3.8 g of $LiAlH_4$ corresponds to 3.8/37.952 = 0.10 mol .....

.....1.8 g of Al corresponds to 1.8/26.98 = 0.067 mol .....

..... flammable gas likely to be H_2 .....

..... $3LiAlH_4(s) \rightarrow 2Al(m) + 3H_2 + \mathbf{Li_3AlH_6}$ .....

.....1 mol ..... 2/3 mol ..1 mol...**B** .....

Question 1

Data: Assume that the molar gas volume = 24.0 $dm^3 mol^{-1}$ at room temperature and pressure (rtp).

a) When lithium metal and hydrogen gas are heated together, a single substance, **A**, is formed as colourless crystals with a melting point of 688 °C. Molten **A** conducts electricity, and electrolysis of the molten substance re-forms the elements.

(i) Give an equation for the formation of **A**.

[1 mark]

Answer: ..... $2Li(m) + H_2(g) \rightarrow 2LiH(s)$ **(A)** .....

.....

(ii) Classify the structure of **A** as either molecular covalent, giant covalent, or ionic. Briefly justify your answer.

[2 marks]

Answer: ..... **ionic** because (1) high melting point and (2) conducts on melting .....

.....

.....

.....

(iii) During the electrolysis of molten **A**, which element appears at the positive electrode (the anode) and which appears at the negative electrode (the cathode)?

[1 mark]

Answer: ..... anode = oxidation: H_2 appears .....

..... cathode = reduction: Li appears .....

b) Substance **A** reacts with aluminium chloride to form lithium aluminium hydride ($LiAlH_4$) and one other by-product.

Give a balanced chemical equation for the formation of lithium aluminium hydride from **A** and aluminium chloride.

[2 marks]

Answer: .....

..... $4LiH(s) + AlCl_3(s) \rightarrow LiAlH_4(s) + 3LiCl(s)$ .....

..... **A** .....

Q# 71/ Cambridge/2017/Section 1 www.SmashingScience.org

47	E

Q# 72/ Cambridge/2017/Section 1 www.SmashingScience.org

52	D

Q# 73/ Cambridge/2016SP/Section 2/ www.SmashingScience.org

Mark Scheme Unavailable ☹

Q# 74/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

40 A

Q# 75/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

41 B

Q# 76/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

45 D

Q# 77/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

46 E

Q# 78/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

50 D

Q# 79/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

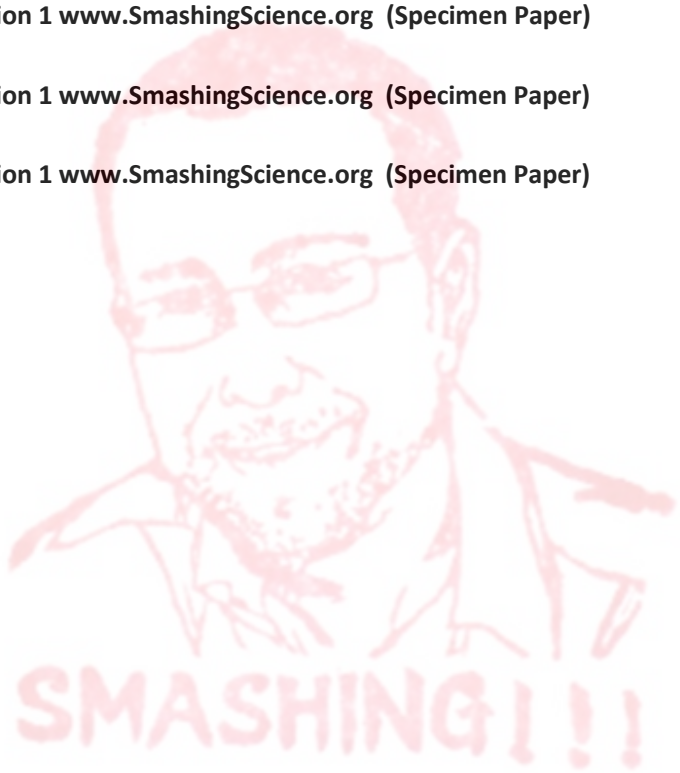
52 E

Q# 80/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

53 C

Q# 81/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

54 D



b) Breakfast cereals frequently have elemental iron added to them as a dietary supplement. A method for making a quantitative measurement of the amount of iron is to use the reaction between $Fe^{3+}(aq)$ and thiocyanate, $SCN^-(aq)$, which gives the deep red complex $FeSCN^{2+}(aq)$.

$$Fe^{3+}(aq) + SCN^-(aq) \rightarrow FeSCN^{2+}(aq)$$

The depth of the colour can be measured using a *spectrophotometer* which gives a value for the *absorbance* that is proportional to the concentration of the complex:

$$\text{absorbance} = \text{constant} \times [FeSCN^{2+}] \qquad \textbf{Equation 1}$$

The constant can be found by measuring the absorbance of a solution of known concentration.

(i) The absorbance of a solution of the complex with concentration 2.5×10^{-4} mol dm^{-3} was measured to be 1.85; determine the value of the constant in Equation 1. **[2 marks]**

Answer:

$$\text{constant} = \frac{1.85}{2.5 \times 10^{-4}} = 7400 \text{ mol}^{-1}\text{dm}^3$$

Units not expected; any reasonable sig. fig. acceptable.

100 g of breakfast cereal was mixed with sufficient dilute acid to dissolve all of the iron. The solution was carefully filtered and mixed with sufficient oxidising agent to convert all of the iron to Fe^{3+}. The solution was made up to a total volume of 250 cm^3. 10.0 cm^3 of this solution was mixed with 10.0 cm^3 of a solution of thiocyanate; you may assume that all of the iron is converted to the complex. The absorbance of the resulting solution was measured as 0.519.

(ii) Using the value of the constant found in **(i)**, calculate the concentration of Fe^{3+} in the solution for which the absorbance was measured. **[2 marks]**

Answer:

There are many possible approaches to this: full credit for any valid approach. Full marks for valid approach and correct answer. Any reasonable sig. fig. for answer acceptable.

$$[Fe^{3+}] \text{ in the measured solution} = \frac{0.519}{7400} = 7.0135 \times 10^{-5} \text{ mol dm}^{-3}$$

(iii) Hence calculate the concentration of Fe^{3+} in the solution prepared from the cereal.

[2 marks]

Answer: .....

.....

$[Fe^{3+}]$ in the 10 cm^3 portion of the extract is twice this $= 1.403 \times 10^{-4}$ mol dm^{-3}; this is the concentration in the 250 cm^3 of extract that was made.

.....

.....

.....

.....

.....

(iv) Hence calculate the mass of iron present in the 100 g of breakfast cereal (A_r: Fe = 55.85).

[4 marks]

Answer: .....

.....

no. of moles in 250 cm^3 solution with this conc $= 1.403 \times 10^{-4} \times \frac{250}{1000} = 3.507 \times 10^{-5}$

convert this to mass of Fe

mass of Fe in 250 cm^3 solution with this conc $= 3.507 \times 10^{-5} \times 55.85 = \mathbf{1.96 \times 10^{-3}\ g}$

This is the mass in 100 g of cereal.

Q# 83/ Cambridge/2016/Section 1 www.SmashingScience.org

41	C

Q# 84/ Cambridge/2016/Section 1 www.SmashingScience.org

42	D

Q# 85/ Cambridge/2016/Section 1 www.SmashingScience.org

46	A

Q# 86/ Cambridge/2016/Section 1 www.SmashingScience.org

50	A

Q# 87/ Cambridge/2016/Section 1 www.SmashingScience.org

51	F

Q# 88/ Cambridge/2016/Section 1 www.SmashingScience.org

52	D

Q# 89/

Q# 90/

Q# 91/

Q# 92/ Cambridge/2022sp/Section 2/ www.SmashingScience.org

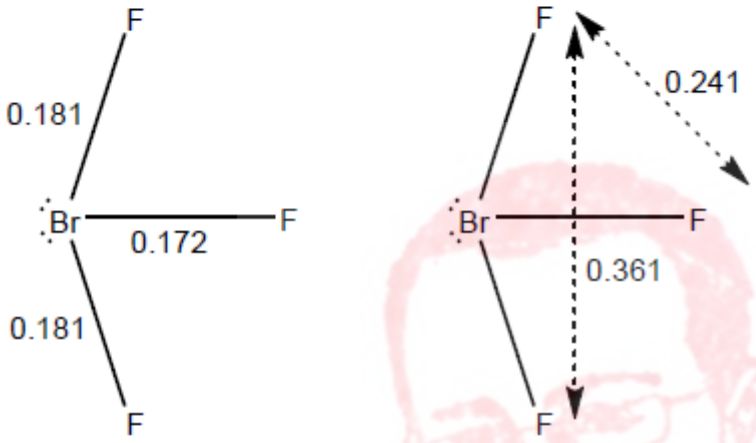
19 G

19 The answer is option **G**.

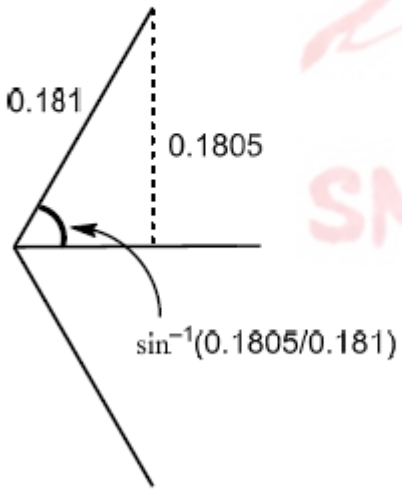
Both bromine and fluorine are in Group 17. F is more electronegative than Br and can form multiple bonds.

Bromine contributes 7 outer electrons to bonding, and the three F atoms contribute one further electron each. So there are 10 outer electrons around the Br centre, i.e. 5 pairs of electron density.

The structure is therefore based on a trigonal bipyramid. As there are only three bonds, two of these regions of electron density are lone pairs. There are several possible shapes that could form according to VSEPR, but only T-shaped would be faithful to the symmetry if only two bond lengths are equal and the third is not.



Finding a right-angled triangle using appropriate distances, and using the inverse sine function ($\sin^{-1}$), gives the bond angle as $\sin^{-1}\left(\frac{0.1805}{0.181}\right)$ (= 86°)



Q# 93/

Q43	C

Q# 94/ Cambridge/2022/Section 2/ www.SmashingScience.org

Q50	G

Q# 95/

Q43	C

Q# 96/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q22	B

Q# 97/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q31	E

Q# 98/ Cambridge/2020SP/Section 2/ www.SmashingScience.org

19 G

Q# 99/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

43 A

43

The answer is option **A**.

Assessment of each option:

A: The high melting and boiling points, together with non-conductivity in the solid and molten states, indicates a giant covalent structure.

B: The high melting and boiling points indicate a giant structure. No conductivity when solid but having conductivity when molten is typical of a giant ionic structure.

C: Despite the relatively low melting and boiling points, the fact that it conducts electricity when solid and molten means that it is a giant metallic structure.

D: With low melting and boiling points, no electrical conductivity and being a liquid at room temperature and pressure, the substance is typical of a simple molecular structure.

E: Despite the very low melting point, the good conductivity when solid and molten indicates a metallic structure. In fact, **E** is mercury.

Q# 100/ Cambridge/2019/Section 1 www.SmashingScience.org

38	C

Q# 101/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

39 A

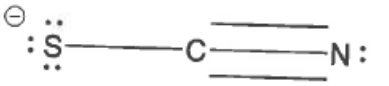
CHEMISTRY

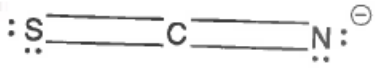
Question 3

Parts **a)**, **b)** and **c)** can be answered independently of one another.

a) Draw two alternative 'dot and cross' diagrams to describe the bonding in the linear thiocyanate anion SCN^-. In one diagram place the negative charge on the sulfur, and in the other place the negative charge on the nitrogen. **[5 marks]**

Answer:





Any variant on these (using lines to represent bonds and/or dot/cross pairs) is acceptable. Crucial thing is to have electron count correct and correct location of lone pairs.

(designed to be 'easy marks')

Q# 103/
Q# 104/

Q# 105/ Cambridge/2022/Section 2/ www.SmashingScience.org

Q52	A

Q# 106/ Cambridge/2022/Section 2/ www.SmashingScience.org

Q60	B

Q# 107/ Cambridge/2022/Section 1 www.SmashingScience.org

Q52	A

Q# 108/ Cambridge/2022/Section 1 www.SmashingScience.org

Q60	B

Q# 109/ Cambridge/2021/Section 1 www.SmashingScience.org

Q56	B

Q# 110/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

53 A

53

The answer is option **A**.

When using a fractionating column, the flask is at the bottom and is heated. The temperature is highest at the bottom of the column and lowest at the top.

The hexane has the lowest boiling point and so will evaporate first in the flask and will rise to the top of the column first (68 °C). The liquid mixture in the flask must be boiling so the temperature must be at least 68 °C, but less than 98 °C, so that only the hexane is vapourised.

Q# 111/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q41	E

Q# 112/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q51	D

Q# 113/ Cambridge/2020/Section 1 www.SmashingScience.org

Q41	E	CHEM

Q# 114/ Cambridge/2020/Section 1 www.SmashingScience.org

Q51	D	CHEM

Q# 115/ Cambridge/2019/Section 1 www.SmashingScience.org

50	B

Q# 116/ Cambridge/2018/Section 1 www.SmashingScience.org

41	B

Q# 117/ Cambridge/2016SP/Section 2/ www.SmashingScience.org

Mark Scheme Unavailable ☹

Q# 118/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

49 A

Q# 119/ Cambridge/2022sp/Section 2/ www.SmashingScience.org

11 D

11 The answer is option **D**.

The heat required to warm the copper container and that required to warm the water are calculated separately using the expression $Q = mc\Delta T$

Copper: $Q_1 = 500 \times 0.4 \times 60 = 12\,000\,\text{J} = 12\,\text{kJ}$

Water: $Q_2 = 400 \times 4 \times 60 = 96\,000\,\text{J} = 96\,\text{kJ}$

Total heat transfer $= Q_1 + Q_2 = 12 + 96 = 108\,\text{kJ}$

This is only 20% of the heat released by burning the methane.

So, total heat released from burning $= 108 \times \frac{100}{20} = 540\,\text{kJ}$

Number of moles of methane burned to release this amount of heat $= \frac{540}{900} = 0.6\,\text{mol}$

Mass of methane $= 0.6 \times 16 = 9.60\,\text{g}$

Q# 120/ Cambridge/2022sp/Section 2/ www.SmashingScience.org

12 A

12 The answer is option **A**.

$\Delta_r H$ is the enthalpy of reaction and $\Delta_f H$ is the enthalpy of formation.

Deduce reaction equation: $HgC_2N_2O_2 \rightarrow Hg + N_2 + 2CO \qquad \Delta_r H = -606\,\text{kJ mol}^{-1}$

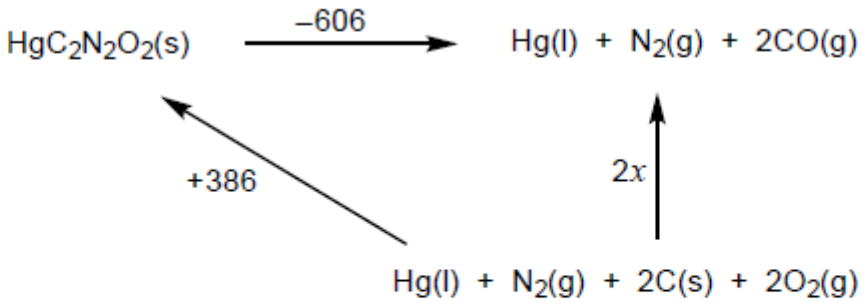
Deduce equation for enthalpy of formation of mercury(II) fulminate:

$$Hg(l) + 2C(s) + N_2(g) + O_2(g) \rightarrow HgC_2N_2O_2(s) \qquad \Delta_f H = +386\,\text{kJ mol}^{-1}$$

Deduce equation for enthalpy of formation of carbon monoxide:

$$C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g) \qquad \Delta_f H = x\,\text{kJ mol}^{-1}$$

Construct a Hess cycle:



$2x = (+386) + (-606) = -220$

$x = -110\,\text{kJ mol}^{-1}$

Q# 121/ Cambridge/2022sp/Section 2/ www.SmashingScience.org

16 B

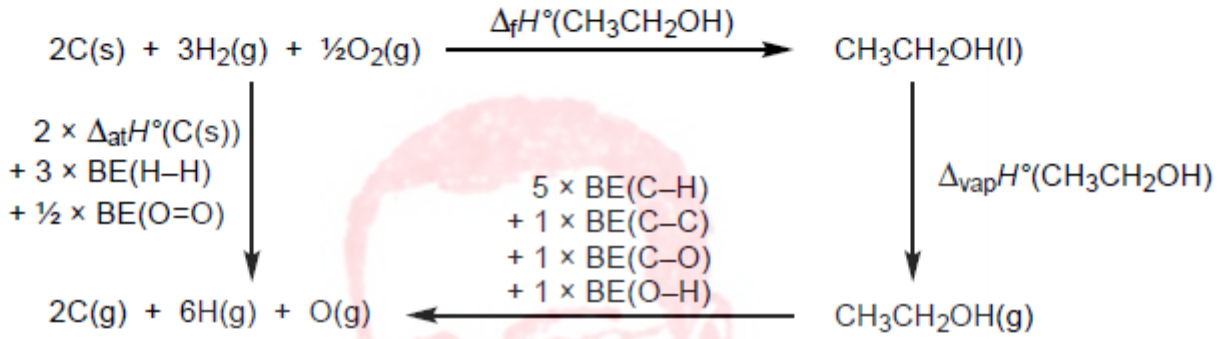
16 The answer is option **B**.

Hess's Law can be used to solve this by creating a Hess Cycle.

The equation for the enthalpy change of formation of ethanol can be set up at the top of the cycle. This enthalpy change is known.

The enthalpy change of vaporisation of ethanol should be included, as by definition the bond enthalpy data is for gaseous covalent bonds.

The gaseous atoms are included such that bond enthalpy (BE) data and atomisation of carbon data can be utilised and the cycle completed:



$$\Delta_f H^\circ(CH_3CH_2OH(l)) = [2(\Delta_{at}H^\circ(C(s)) + 3(BE(H-H)) + 0.5(BE(O=O))]$$
$$- [5(BE(C-H)) + BE(C-C) + BE(C-O) + BE(O-H)]$$
$$- [\Delta_{vap}H^\circ(CH_3CH_2OH(l))]$$

$$-277 = [2987] - [5(BE(C-H)) + 1167] - [39]$$

$$5(BE(C-H)) = +277 + 2987 - 1167 - 39$$
$$= +2058$$

$$BE(C-H) = +\frac{2058}{5}$$
$$= +412\,kJ\,mol^{-1}$$

Q# 122/ Cambridge/2022/Section 2/ www.SmashingScience.org

Q57	F

Q# 123/ Cambridge/2022/Section 1 www.SmashingScience.org

Q57	F

Q# 124/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q27	A

Q# 125/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q34	F

Q# 126/ Cambridge/2021/Section 1 www.SmashingScience.org

Q54	E

Q# 127/ Cambridge/2021/Section 1 www.SmashingScience.org

Q55	A

Q# 128/ Cambridge/2020SP/Section 2/ www.SmashingScience.org

11 D

Q# 129/ Cambridge/2020SP/Section 2/ www.SmashingScience.org

12 A

Q# 130/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

47 D

47

The answer is option **D**.

Bond breaking is an endothermic process, whilst bond making is an exothermic process.

The reaction is exothermic overall, which means that more energy is released when bonds are made than is needed for bonds to be broken.

The bonds to be broken are on the left of the equation $(1\times N\equiv N$ and $3\times H-H)$ and those made are on the right of the equation $(2\times 3\times N-H)$. This means that the 6 N—H bond energies must be greater than the N_2 and $3\times H_2$ bond energies in total.

Looking at the number of bonds from the mole ratios in the equation (1 : 3 : 2), the inequality $6z > x + 3y$ is satisfied.

Q# 131/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q58	D

Q# 132/ Cambridge/2020/Section 1 www.SmashingScience.org

Q58	D	CHEM

Q# 133/ Cambridge/2019/Section 1 www.SmashingScience.org

53	B

Q# 134/ Cambridge/2017/Section 1 www.SmashingScience.org

49	E

Q# 135/ Cambridge/2017/Section 1 www.SmashingScience.org

51	A

Q# 136/ Cambridge/2016SP/Section 2/ www.SmashingScience.org

Mark Scheme Unavailable ☹

Q# 137/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

43 E

Q# 138/ Cambridge/2016/Section 2/ www.SmashingScience.org

f) Use the data to calculate the standard enthalpy change of combustion of alkene **P**.

[4 marks]

Answer: .....

.....

.....

..... $C_5H_{10} + H_2 \rightarrow C_5H_{12}$ $\Delta H_1 = -113$

..... $C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$ $\Delta H_2 = -3528$

..... $H_2O \rightarrow H_2 + \frac{1}{2}O_2$ $\Delta H_3 = +286$

..... Adding all three gives

..... $C_5H_{10} + (7/2)O_2 \rightarrow 5CO_2 + 5H_2O$ $\Delta H = \Delta H_1 + \Delta H_2 + \Delta H_3 = -113 - 3528 + 286 =$ **-3355 kJ mol^{-1}**

.....

Q# 139/ Cambridge/2016/Section 1 www.SmashingScience.org

48	F

Q# 140/ Cambridge/2016/Section 1 www.SmashingScience.org

54	C

Q# 141/

Q45	D

Q# 142/

Q45	D

Q# 143/ Cambridge/2021/Section 1 www.SmashingScience.org

Q48	D

Q# 144/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

48 C

48

The answer is option **C**.

Equations 2 and 3 are correct.

(Construction of half-equations is another valid solution method with the same conclusion.)

Oxidising agents accept electrons. Reducing agents lose (or donate) electrons.

Looking at each equation for the first reactant in the equation in turn:

1: Mg is transformed into Mg^{2+}. Electrons are being lost and so Mg is a reducing agent.

2: The oxidation state of chromium in the first compound is +6 and it is transformed into Cr^{3+}. Electrons are being accepted and so $Cr_2O_7^{2-}$ is an oxidising agent.

3: Cu^{2+} is transformed into Cu^{+}. Electrons are being accepted and so Cu^{2+} is a oxidising agent.

4: The oxidation state of sulfur in the first compound is +4 and it is transformed into a compound where it is +6. Electrons are being lost and so the first compound is a reducing agent.

Q# 145/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q50	C

Q# 146/ Cambridge/2020/Section 1 www.SmashingScience.org

Q50	C	CHEM

Q# 147/ Cambridge/2019/Section 1 www.SmashingScience.org

44	B

Q# 148/ Cambridge/2018/Section 1 www.SmashingScience.org

43	F

Q# 149/ Cambridge/2017/Section 1 www.SmashingScience.org

43	D

Q# 150/ Cambridge/2017/Section 1 www.SmashingScience.org

44	D

Q# 151/ Cambridge/2016SP/Section 2/ www.SmashingScience.org

Mark Scheme Unavailable ☹

Q# 152/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

44 C

c) Hydrogen peroxide, H_2O_2, is used as the oxidising agent to convert Fe^{2+} to Fe^{3+} in the assay described in **b)(ii)**.

(i) Determine the oxidation state of oxygen in H_2O_2. **[2 marks]**

Answer: .....

Let *x* be the oxidation state of O, assume oxidation state of H is +1; species is neutral so

$$2 \times (+1) + 2 \times x = 0$$

Hence *x* = −1

(ii) When H_2O_2 acts as an oxidising agent in acidic solution, what is the oxygen-containing species that is produced and what is the oxidation state of oxygen in this species? **[4 marks]**

Answer: .....

(ii) H_2O_2 is reduced to **H_2O**. Oxidation state of O in H_2O is **−2**.

2 marks for each

(iii) Write a balanced chemical equation describing the oxidation of $Fe^{2+}(aq)$ to $Fe^{3+}(aq)$ by H_2O_2 in acidic solution. **[4 marks]**

Answer: .....

(iii) **$2Fe^{2+}(aq) + H_2O_2(aq) + 2H^+(aq) \rightarrow 2Fe^{3+}(aq) + 2H_2O(l)$**

Looking for charges and atoms to balance; not worried about (aq) etc; H_3O^+ fine instead of H^+.

Q# 154/ Cambridge/2016/Section 1 www.SmashingScience.org

45	C

Q# 155/ Cambridge/2022/Section 2/ www.SmashingScience.org

Q56	C

Q# 156/

Q48	F

Q# 157/ Cambridge/2022/Section 1 www.SmashingScience.org

Q56	C

Q# 158/ Cambridge/2021/Section 1 www.SmashingScience.org

Q45	D

Q# 159/ Cambridge/2021/Section 1 www.SmashingScience.org

Q53	A

Q# 160/ Cambridge/2020SP/Section 2/ www.SmashingScience.org

16 C

Q# 161/ Cambridge/2020SP/Section 2/ www.SmashingScience.org

20 C

Q# 162/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

41 E

41

The answer is option **E**.

The pH scale is a measure of the acidity or alkalinity of an aqueous solution.

All indicators in the mixture experience a pH of 5.0.

Methyl orange (colour change at 4.0) will be yellow at pH 5.0.

Bromothymol blue (colour changes at 6.5) will be yellow at pH of 5.0.

Phenolphthalein (colour changes at 9.0) will be colourless at pH of 5.0.

In order: yellow + yellow + colourless = yellow.

Q# 163/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

55 E

55

The answer is option **E**.

A: False. There is a different number of molecules on the two sides of the equation so altering the pressure will shift the equilibrium position.

B: False. The reaction is exothermic and so increasing the temperature will move the equilibrium position to the left.

C: False. Chemical equilibrium is dynamic so reactants are constantly changing to products and products are constantly changing back to reactants.

D: False. A catalyst increases the rate at which equilibrium is reached but does not shift the position of equilibrium.

E: Correct. Until equilibrium is reached, the forward reaction will be faster than the backward reaction.

Q# 164/ Cambridge/2020/Section 1 www.SmashingScience.org

Q54	G	CHEM

Q# 165/ Cambridge/2020/Section 1 www.SmashingScience.org

Q60	F	CHEM

Q# 166/ Cambridge/2018/Section 1 www.SmashingScience.org

38	C

Q# 167/ Cambridge/2018/Section 1 www.SmashingScience.org

45	E

Q# 168/ Cambridge/2018/Section 1 www.SmashingScience.org

54	E

Q# 169/ Cambridge/2017/Section 1 www.SmashingScience.org

38	B

Q# 170/ Cambridge/2017/Section 1 www.SmashingScience.org

39	H

Q# 171/ Cambridge/2017/Section 1 www.SmashingScience.org

40	A

Q# 172/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

37 E

Q# 173/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

51 E

Q# 174/ Cambridge/2016/Section 1 www.SmashingScience.org

40	C

Q# 175/ Cambridge/2016/Section 1 www.SmashingScience.org

49	F

Q# 176/

Q46	A

Q# 177/

Q46	A

Q# 178/ Cambridge/2021/Section 1 www.SmashingScience.org

Q58	F

Q# 179/ Cambridge/2021/Section 1 www.SmashingScience.org

Q60	A

Q# 180/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

60 B

60

The answer is option **B**.

The reaction is faster than the original as it is hotter and the acid is more concentrated. The number of moles of acid reacting is the same as the volume is half of the original but the concentration double. Given that the acid is the limiting reagent with the calcium carbonate in excess, the volume of carbon dioxide formed will be the same as the original.

Q# 181/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q53	D

Q# 182/ Cambridge/2020/Section 1 www.SmashingScience.org

Q53	D	CHEM

Q# 183/ Cambridge/2019/Section 1 www.SmashingScience.org

49	D

Q# 184/ Cambridge/2018/Section 1 www.SmashingScience.org

50	A

Q# 185/ Cambridge/2017/Section 1 www.SmashingScience.org

48	D

Q# 186/ Cambridge/2017/Section 1 www.SmashingScience.org

53	C

Q# 187/ Cambridge/2016/Section 1 www.SmashingScience.org

44	E

Q# 188/ Cambridge/2021/Section 1 www.SmashingScience.org

Q41	F

Q# 189/ Cambridge/2021/Section 1 www.SmashingScience.org

Q44	E

Q# 190/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

46 E

46

The answer is option **E**.

Mass number = number of protons + number of neutrons = 40

Atomic number = number of protons = 20

Number of protons = 20, so number of electrons = 20 to balance charge.

Number of neutrons = 40 – 20 = 20

Using the above information and applying it to each statement:

1: Incorrect. The relative mass of the nucleus is 40.

2: Incorrect. A total of 20 electrons would give an electronic configuration of 2,8,8,2. The incomplete outer shell containing two electrons indicates that is in Group 2. Group 2 elements are not noble gases, they are alkaline earth metals.

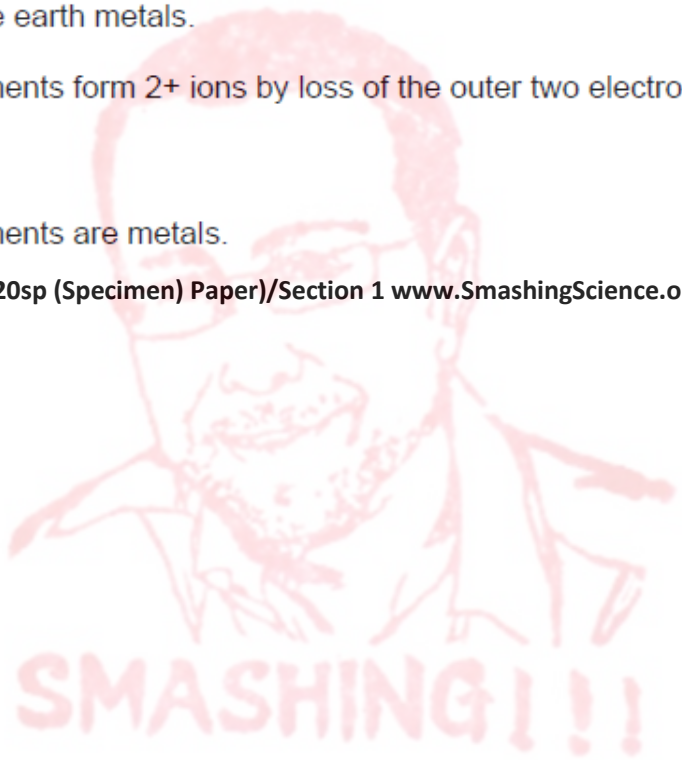
3: Incorrect. Group 2 elements form 2+ ions by loss of the outer two electrons.

4: Correct.

5: Incorrect. Group 2 elements are metals.

Q# 191/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

51 C



51

The answer is option **C**.

Electron configurations of atoms can be used to identify the position of an element in the Periodic Table. The number of electrons in the outer shell determines the group. The number of shells determines in which period the element is.

A: 2,4 Group 14, where non-metals are at the top of the group and metals are at the bottom

B: 2,6 Group 16, a non-metal

C: 2,7 Group 17, a non-metal

D: 2,8,1 Group 1, a metal

E: 2,8,6 Group 16, a non-metal

F: 2,8,7 Group 17, a non-metal

Only **D** can be eliminated. Non-metals react to gain electrons and acquire the configurations of noble gases.

The fewer the electrons to gain, the more reactive the element. This narrows the choice down to **C** and **F**, as both atoms only need to gain one electron.

C is the smaller atom (two shells) so there is more attraction between the nucleus and the electron to be gained, compared with **F**. **C** will therefore be more reactive. The element is fluorine.

Q# 192/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q47	F

Q# 193/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q57	G

Q# 194/ Cambridge/2020/Section 1 www.SmashingScience.org

Q42	F	CHEM

Q# 195/ Cambridge/2020/Section 1 www.SmashingScience.org

Q47	F	CHEM

Q# 196/ Cambridge/2019/Section 2/ www.SmashingScience.org

a) Minimum oxidation state = -2 (Te needs 2 electrons for noble gas configuration)
Maximum oxidation state = +6 (all six of its valence electrons being used in bond formation). **[3]**

b) Electronegativity decreases on moving down a group. **[1]**

c) (Generally boiling points for analogous hydrides in a group would increase with the mass of the molecule), but due to hydrogen bonding. H_2O would have the higher boiling point. **[2]**

Q# 197/ Cambridge/2019/Section 1 www.SmashingScience.org

41	H

Q# 198/ Cambridge/2019/Section 1 www.SmashingScience.org

51	D

Q# 199/ Cambridge/2018/Section 1 www.SmashingScience.org

42	E

Q# 200/ Cambridge/2018/Section 1 www.SmashingScience.org

44	A

Q# 201/ Cambridge/2018/Section 1 www.SmashingScience.org

46	C

Q# 202/ Cambridge/2017/Section 1 www.SmashingScience.org

42	C

Q# 203/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

42 E

Q# 204/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

47 C

Q# 205/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q42	F

Q# 206/ Cambridge/2022/Section 2/ www.SmashingScience.org

Q55	D

Q# 207/ Cambridge/2022/Section 2/ www.SmashingScience.org

Q59	E

Q# 208/ Cambridge/2022/Section 1 www.SmashingScience.org

Q54	E

Q# 209/ Cambridge/2022/Section 1 www.SmashingScience.org

Q59	E

Q# 210/ Cambridge/2020/Section 2/ www.SmashingScience.org

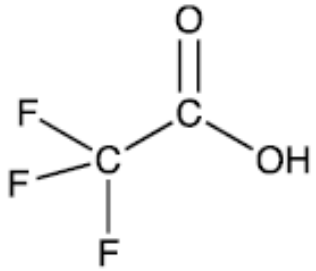
Q44	B

Q# 211/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q55	C

Q# 212/ Cambridge/2019/Section 2/ www.SmashingScience.org

Answers for Question 2



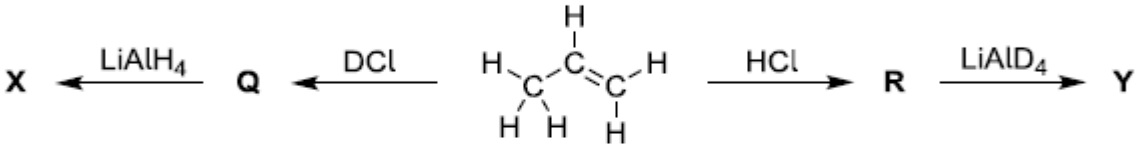
a) Angles round CF3 carbon approximately 109.5°.
Angles round carbonyl carbon approximately 120°. **[2]**

Q# 213/ Cambridge/2019/Section 1 www.SmashingScience.org

37	F

d) Lithium aluminium deuteride can be prepared if deuterium gas is used in place of normal hydrogen. Deuterium, often give the symbol D, is the non-radioactive isotope of hydrogen, *i.e.* D = ^{2}H. The formula for lithium aluminium deuteride can be written $LiAlD_4$. Both $LiAlH_4$ and $LiAlD_4$ are common reducing agents and the latter is useful for preparing deuterium-containing compounds.

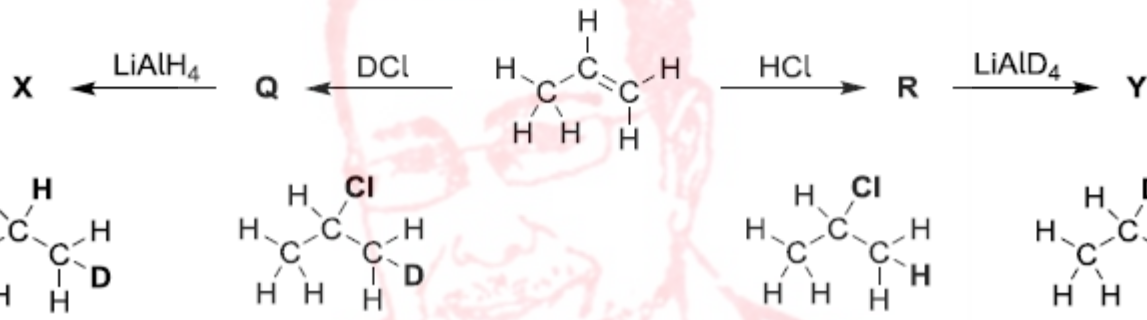
Isomers of mono-deuterated propane, **X** and **Y**, may be prepared from propene according to the following scheme which also uses hydrogen chloride, HCl, and deuterium chloride, DCl. In the scheme, only the carbon-containing compounds are shown; other by-products are not.



Give the structures of **X** and **Y** and the intermediates **Q** and **R** formed during the syntheses.

[4 marks]

Answer: .....



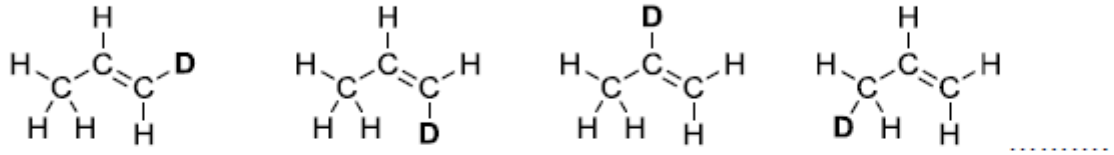
...

e) 2,2-dideuterated propane may be prepared easily in two steps, from a mono-deuterated propene, **Z**. (The formula for **Z** is C_3H_5D.)

(i) Draw the structures of all the alkenes with formula C_3H_5D.

[2 marks]

Answer: .....

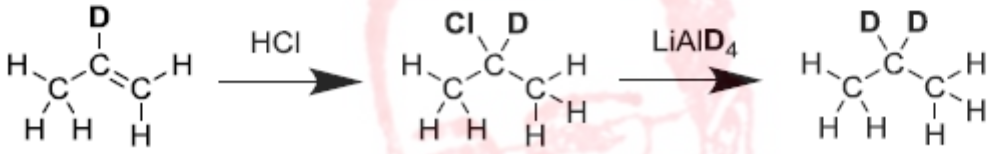


.....

(ii) Give a synthesis of 2,2-dideuterated propane starting from **Z** showing reagents and intermediates in each step.

[3 marks]

Answer: .....



Z

.....

.....

Q# 215/ Cambridge/2016SP/Section 2/ www.SmashingScience.org
Mark Scheme Unavailable ☹

Q# 216/ Cambridge/2016/Section 2/ www.SmashingScience.org

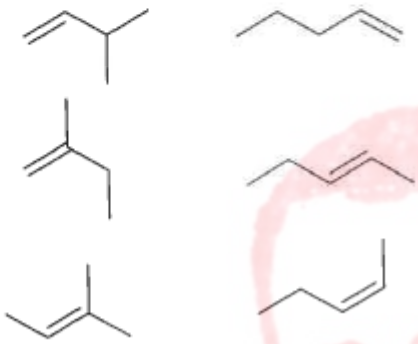
Question 4

There are six isomers with the formula C_5H_{10} that are alkenes. The alkenes all have different enthalpies of formation, all of which are negative.

a) Draw the structures of the six alkenes (skeletal or displayed structures are acceptable).

[6 marks]

Answer:



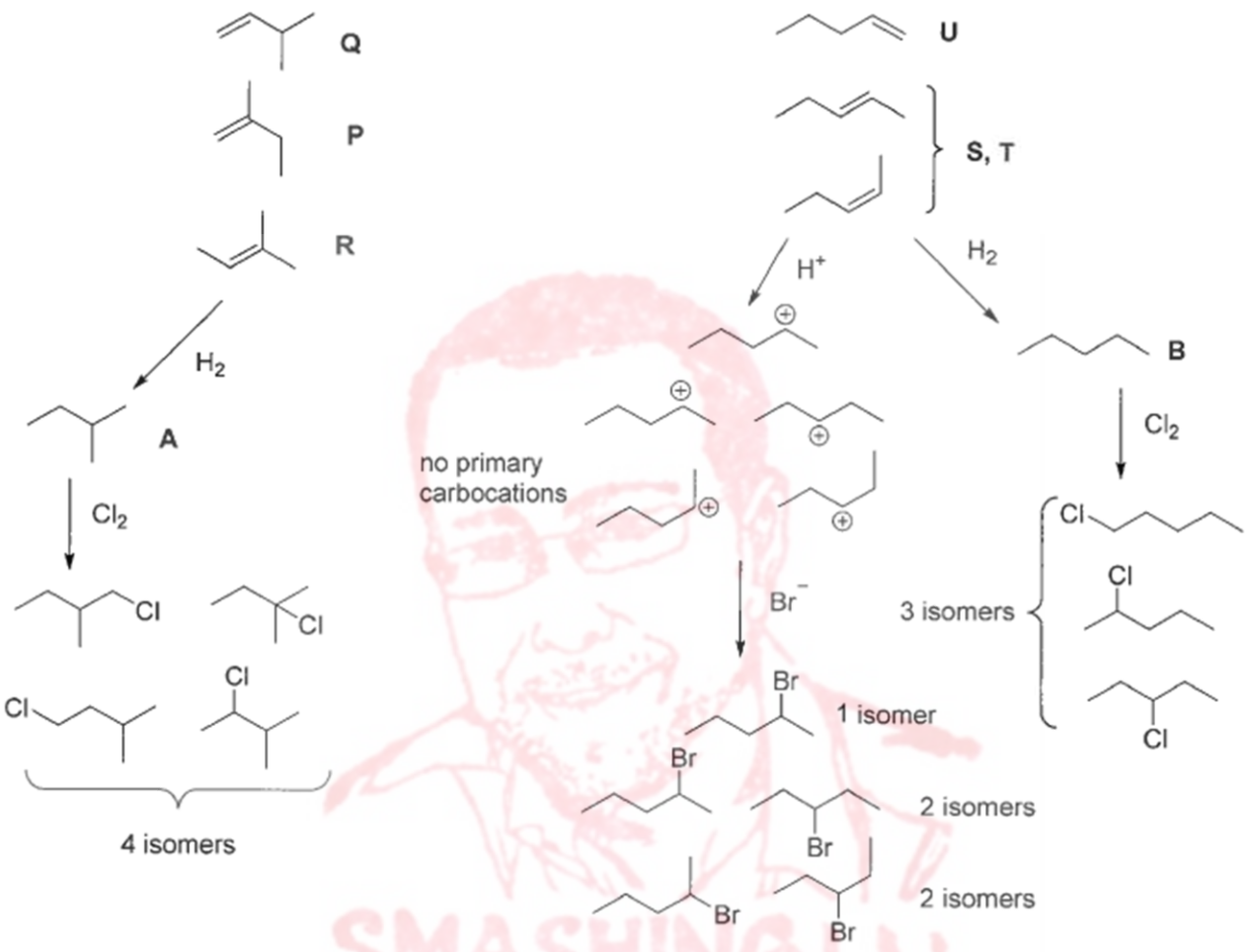
Other ways of writing out the structures are fine as long as they are clear

Q# 217/ Cambridge/2016/Section 2/ www.SmashingScience.org

CHEMISTRY

Guidance for markers – not the expected answer from candidates

The overall scheme is



Samples of the six alkenes, in a random order, are labelled **P**, **Q**, **R**, **S**, **T**, and **U**. You will be able to identify which isomer *some* of these correspond to using the information and data throughout the rest of the question.

Alkenes **P**, **Q**, and **R** react with hydrogen gas and a metal catalyst to give the same alkane **A**; alkenes **S**, **T**, and **U** react under the same conditions to give a different alkane **B**.

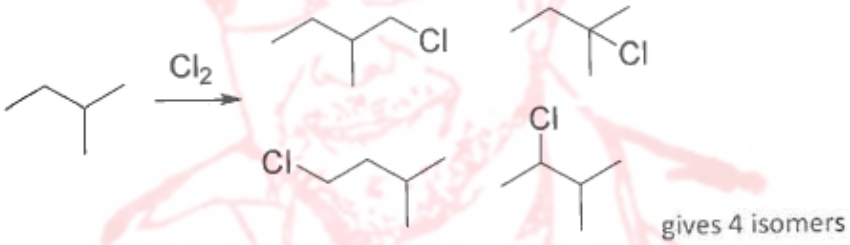
Both alkanes **A** and **B** react with chlorine gas under UV light to form chloroalkanes with the formula $C_5H_{11}Cl$. Under such conditions, alkane **A** forms *four* different structural isomers, whereas **B** gives *three*.

b) Draw the structures of alkanes **A** and **B**. Also draw the structures of the four isomers arising from the chlorination of **A**, and the three isomers arising from the chlorination of **B**. **[6 marks]**

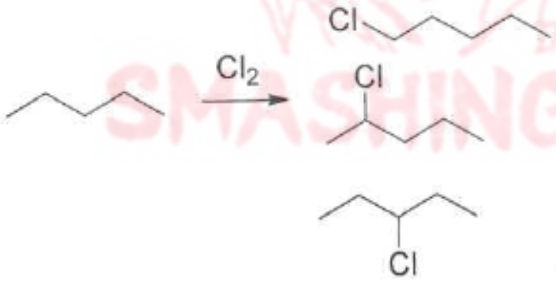
Answer:

Realise that there are only two hydrogenation products

Chlorination of these gives several products corresponding to putting one Cl onto each distinct carbon



gives 4 isomers



gives 3 isomers

Identifies

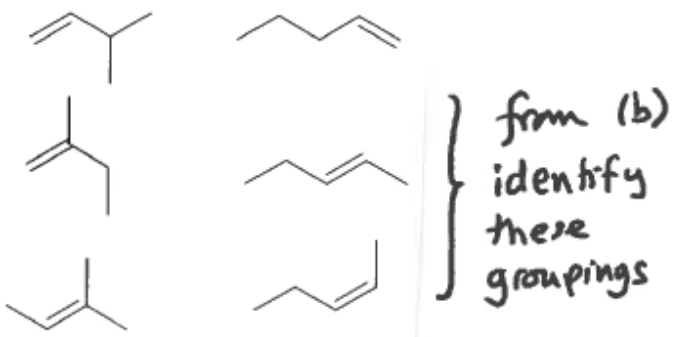
A B

N.B. reasoning is not requested or required

The alkenes react with HBr to form bromoalkanes with the formula $C_5H_{11}Br$; the reaction proceeds via a carbocation intermediate. Alkenes **S** and **T** give a mix of *two* structural isomers, whereas alkene **U** gives only one.

c) Give the structure of alkene **U**. **[4 marks]**

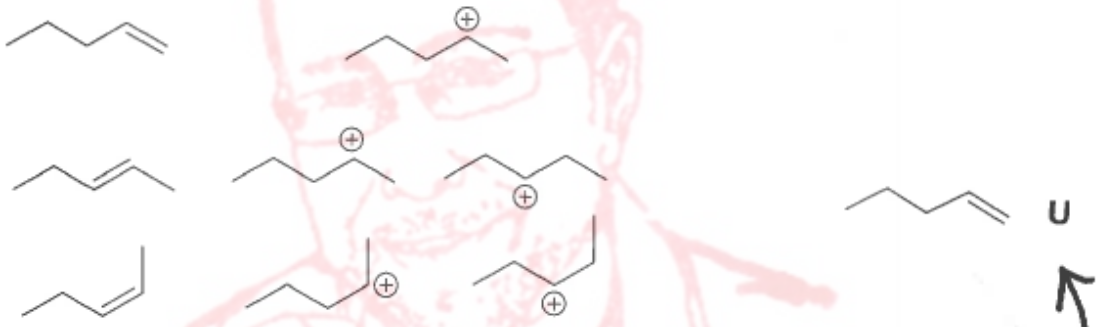
Answer:



from (b) identify these groupings

P, Q, R **S, T, U**

The cations arising from **S, T, U** group are (primary excluded)



U

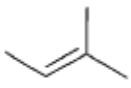
Only the first one will give one isomer on subsequent reaction with Br^-, identifying

A general rule for isomeric alkenes is that the more carbon atoms directly bonded to the double bond (or the lower the number of hydrogen atoms directly bonded), the more negative (that is, the more exothermic) the enthalpy of formation of the alkene.

d) Out of **P**, **Q** and **R**, **R** has the most negative (most exothermic) enthalpy of formation. Give the structure of **R**. **[1 mark]**

Answer:

Out of **P**, **Q** and **R**, the one with the most carbons attached to the double bond is



R

R has the most negative (most exothermic) enthalpy of formation.

Consider the following thermodynamic data:

	value / kJ mol^{-1}
standard enthalpy change of hydrogenation for alkene **P**	–113
standard enthalpy change of hydrogenation for alkene **Q**	–119
standard enthalpy change of combustion for alkane **A**	–3528
standard enthalpy change of formation of $H_2O(l)$	–286

e) Use the data to deduce the structure of: **(i)** alkene **P**; and **(ii)** alkene **Q**. **[4 marks]**

Answer: .....

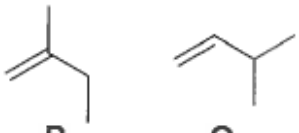
.....

Hydrogenation of both **P** and **Q** gives **A**, we can assess the enthalpies of formation of **P** and **Q** by comparing their enthalpies of hydrogenation.

P/Q + H_2 → **A**

ΔH for this reaction is $\Delta_r H$(hydrogenation) = $\Delta_f H$(**A**) – $\Delta_f H$(**P/Q**)
hence $\Delta_f H$(**P/Q**) = $\Delta_f H$(**A**) – $\Delta_r H$(hydrogenation).

Since $\Delta_r H$(hydrogenation) is more negative for **Q** than for **P**, – $\Delta_r H$(hydrogenation) is more positive for **Q** than for **P**. It follows that $\Delta_f H$(**Q**) is larger than $\Delta_f H$(**P**) i.e. $\Delta_f H$(**Q**) is less negative than $\Delta_f H$(**P**). **P** therefore has the more substituted double bond



P **Q**

An alternative is to work out $\Delta_r H$ for **P** → **Q** in the following way

$\Delta_r H$(hydrogenation **P**) = $\Delta_f H$(**A**) – $\Delta_f H$(**P**) –113 kJ mol^{-1}
$\Delta_r H$(hydrogenation **Q**) = $\Delta_f H$(**A**) – $\Delta_f H$(**Q**) –119 kJ mol^{-1}

subtracting second from first gives

$\Delta_r H$(hydrogenation **P**) – $\Delta_r H$(hydrogenation **Q**) = $\Delta_f H$(**Q**) – $\Delta_f H$(**P**) –113 + 119 = 6 kJ mol^{-1}

This is $\Delta_r H$ for **P** → **Q**. The positive value implies that $\Delta_f H$(**P**) is more negative than $\Delta_f H$(**Q**): **P** has the more substituted double bond.

Q# 219/ Cambridge/2022sp/Section 2/ www.SmashingScience.org

15 A

15 The answer is option **A**.

The oxidation state of silver in Tollens' reagent is +1, as NH_3 is a neutral species and the nitrate anion has a charge of –1.

It acts as a reducing agent as shown by the half-equation: $Ag^+(aq) + e^- \rightarrow Ag(s)$

Combining this with the organic oxidation half-equation shows that the overall reaction has the stoichiometry:

$$2Ag^+(aq) + RCHO + H_2O \rightarrow 2Ag(s) + RCOOH + 2H^+$$

The internal surface area of the beaker is the area of the circular base added to the curved sides.

Surface area to be coated $= \pi r^2 + 2\pi rh = 25\pi + 100\pi = 125\pi\,cm^2$

Volume of silver required = surface area × thickness $= 125\pi\,cm^2 \times 0.01\,cm = 1.25\pi\,cm^3$

Mass of silver required in g = volume × density $= 1.25\pi\,cm^3 \times 10.5\,g\,cm^{-3}$

Number of moles of Ag(s) required $= \frac{\text{mass in g}}{A_r(Ag)} = \frac{10.5 \times 1.25 \times \pi}{108}$

So, the number of moles of aldehyde required $= \frac{1}{2} \times \frac{10.5 \times 1.25 \times \pi}{108}$

Q# 220/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q23	C

Q# 221/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q33	C

Q# 222/ Cambridge/2018/Section 1 www.SmashingScience.org

48	D

Q# 223/ Cambridge/2022/Section 2/ www.SmashingScience.org

Q49	H

Q# 224/

Q49	H

Q# 225/ Cambridge/2021/Section 1 www.SmashingScience.org

Q49	C

Q# 226/ Cambridge/2022/Section 2/ www.SmashingScience.org

Q54	E

Q# 227/ Cambridge/2021/Section 1 www.SmashingScience.org

Q46	E

Q# 228/ Cambridge/2020SP/Section 2/ www.SmashingScience.org

18 E

Q# 229/ Cambridge/2022sp/Section 2/ www.SmashingScience.org

13 B

13 The answer is option **B**.

The hydrocarbon contains 14.3% by mass of H, so must contain 85.7% by mass of C.

The empirical formula of X is found by considering the ratio C : H which is $\frac{85.7}{12} : \frac{14.3}{1}$, cancelling to 2 : 1 by approximation.

Therefore the empirical formula is CH_2.

The mass spectrum shows the molecular ion peak at $m/z = 84$, so $M_r = 84$.

The molecular mass of cyclobutane (C_4H_8) is 56. This corresponds to the highest intensity peak, but that does not correspond to the molecular ion.

Molecular formula of X is therefore: C_6H_{12}

X does not react with bromine, so it is not an alkene. X cannot be hex-2-ene.

X must be a cycloalkane with 6 C atoms, such as cyclohexane.

Q# 230/ Cambridge/2022/Section 1 www.SmashingScience.org

Q51	C

Q# 231/ Cambridge/2021/Section 1 www.SmashingScience.org

Q51	B

Q# 232/ Cambridge/2020SP/Section 2/ www.SmashingScience.org

13 B

Q# 233/ Cambridge/2019/Section 1 www.SmashingScience.org

40	G

Q# 234/ Cambridge/2018/Section 1 www.SmashingScience.org

40	D

Q# 235/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

48 C

Q# 236/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q39	F

Q# 237/ Cambridge/2019/Section 2/ www.SmashingScience.org

j) $CF_3COOCOCF_3 + H_2O \longrightarrow 2\ CF_3COOH$

k) $\Delta H = -36.7 - 75.6 + 98.3 = -14.0\ kJ\ mol^{-1}$.

Q# 238/ Cambridge/2017/Section 2/ www.SmashingScience.org

Question 2

Read the preamble carefully before proceeding to answer the question.

In their solid (crystalline) form many inorganic salts (such as NaCl or MgF_2) can be thought of as consisting of a giant lattice in which positive ions (*e.g.* Na^+, Mg^{2+}) and negative ions (*e.g.* Cl^-, F^-) are arranged in a regular pattern, called a *lattice*. The ions are held together by electrostatic forces arising from the favourable interactions between ions of opposite charge.

The lattice enthalpy is the enthalpy change for a process in which the *solid* material is formed from ions in the gas phase. For NaCl(s) this is the process

$$Na^+(g) + Cl^-(g) \rightarrow NaCl(s)$$

and for MgF_2 the process is

$$Mg^{2+}(g) + 2F^-(g) \rightarrow MgF_2(s)$$

The lattice enthalpy is invariably large and negative.

The lattice enthalpy in $kJ\,mol^{-1}$ can be estimated using the following expression

$$\frac{-1.07\times10^5\times n_{ions}\times z_+\times z_-}{r_+ + r_-} \qquad \textbf{Equation 1}$$

In this expression, r_+ is the radius of the positive ion, in pm ($1\,pm = 10^{-12}\,m$), and r_- is the radius of the negative ion, also given in pm.

n_{ions} is the number of ions in the formula unit; for example, for NaCl $n_{ions} = 2$, but for MgF_2 $n_{ions} = 3$.

z_+ is the charge number on the positive ion; for example for Na^+ it is 1, but for Mg^{2+} it is 2. z_- is likewise the *absolute value* of the charge number on the negative ion: for Cl^- it is 1 (*not* −1).

a) Use Equation 1 to calculate the lattice enthalpy for CuF_2 given the following data:

$$r_+ = 73\,pm, \quad r_- = 133\,pm$$

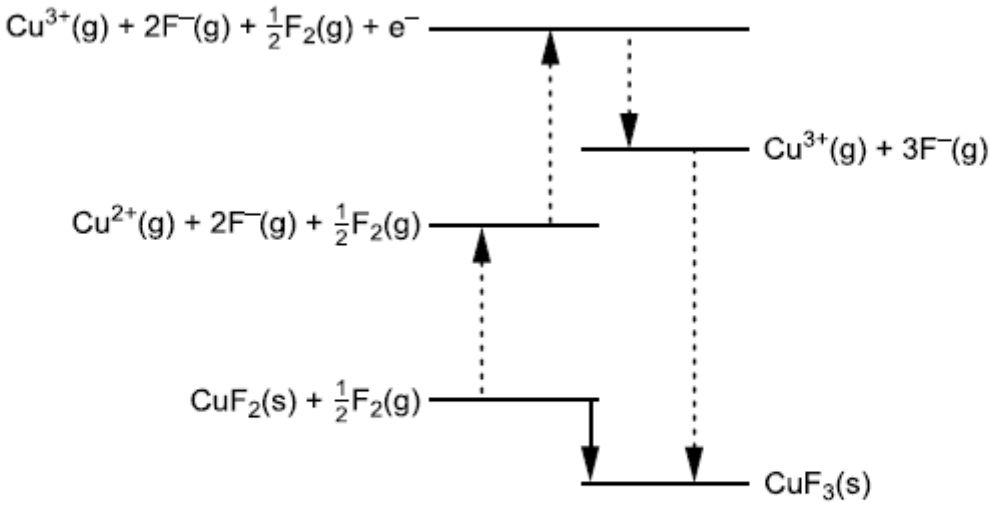
[3 marks]

Answer: .....

..... $\frac{-1.07\times10^5\times3\times2\times1}{73+133} = -3120\,kJ\,mol^{-1}$ .....

.....

d) The enthalpy change for the reaction in Equation 2 can be calculated using the following Hess's Law cycle.



Using your results from parts **a)** and **b)**, and given the following enthalpy changes below

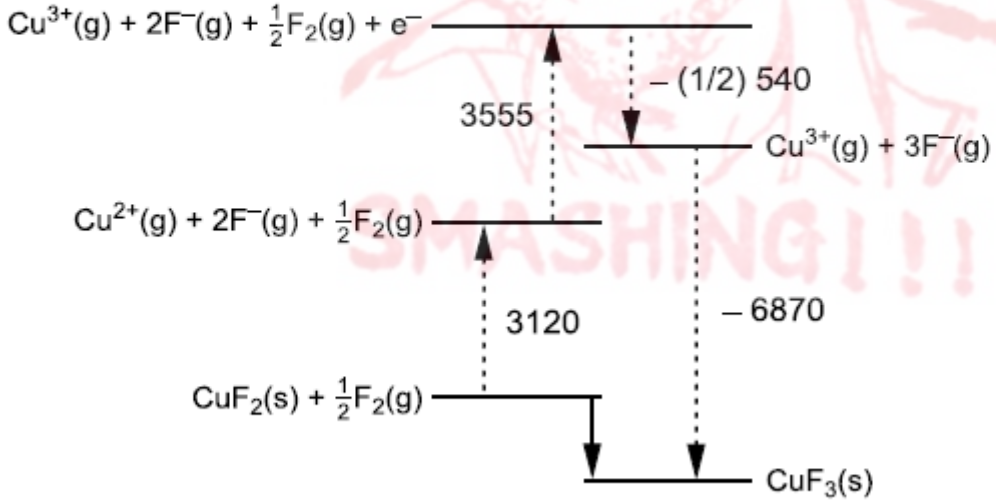
$$F_2(g) + 2e^- \rightarrow 2F^-(g) \qquad \Delta H = -540\,kJ\,mol^{-1}$$
$$Cu^{2+}(g) \rightarrow Cu^{3+}(g) + e^- \qquad \Delta H = 3555\,kJ\,mol^{-1}$$

calculate the enthalpy change for:

$$CuF_2(s) + \tfrac{1}{2}F_2(g) \rightarrow CuF_3(s)$$

[5 marks]

Answer: …



…

…Required value is 3120 + 3555 – (1/2) 540 – 6870 = **– 465 kJ mol^{-1}**….

b) Use Equation 1 to calculate the lattice enthalpy for CuF_3 given the following data:

$$r_+ = 54\,\text{pm}, \quad r_- = 133\,\text{pm}$$

[3 marks]

Answer: .....

..... $\dfrac{-1.07\times10^5\times4\times3\times1}{54+133} = -6870\,\text{kJ mol}^{-1}$ .....

.....

.....

.....

c) Calculated values of the lattice enthalpy can be used to estimate the enthalpy change of hypothetical reactions, such as

$$CuF_2(s) + \tfrac{1}{2}F_2(g) \rightarrow CuF_3(s) \qquad \textbf{Equation 2}$$

Determine the oxidation state of copper in each of the species and hence classify what kind of reaction this is.

[3 marks]

Answer: .....

.....CuF_2: assume F = −1, so Cu is +2 (as species neutral) .....

..... CuF_3: assume F = −1, so Cu is +3 (as species neutral).....

.....This is a redox reaction.....

e) Use the data given below to calculate the enthalpy change for the following reaction (M is an unspecified metallic element).

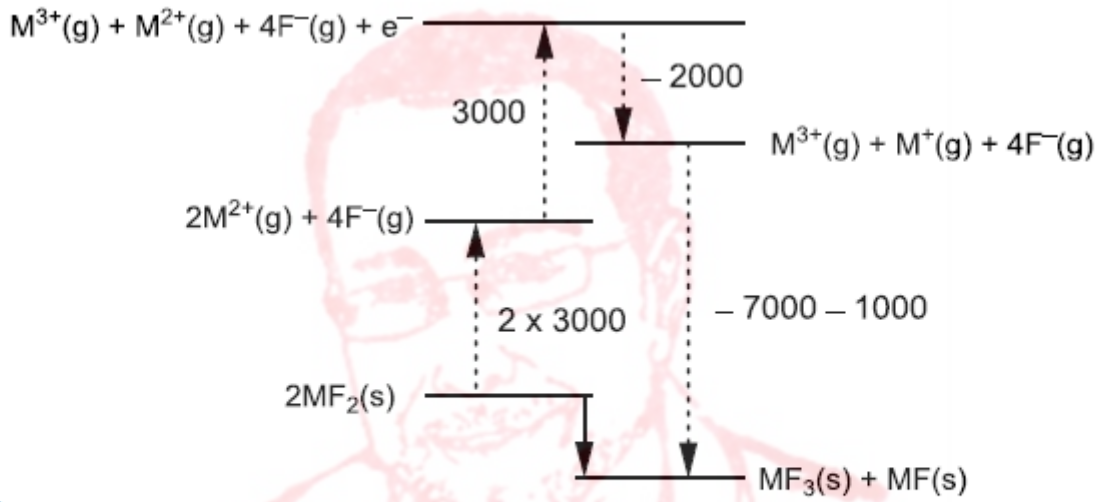
$$2MF_2(s) \rightarrow MF_3(s) + MF(s)$$

You may find it helpful to start by constructing an appropriate Hess's Law cycle.

$MF_2(s) \rightarrow M^{2+}(g) + 2F^-(g)$	$\Delta H = 3000\,kJ\,mol^{-1}$
$MF_3(s) \rightarrow M^{3+}(g) + 3F^-(g)$	$\Delta H = 7000\,kJ\,mol^{-1}$
$MF(s) \rightarrow M^{+}(g) + F^-(g)$	$\Delta H = 1000\,kJ\,mol^{-1}$
$M^{+}(g) \rightarrow M^{2+}(g) + e^-$	$\Delta H = 2000\,kJ\,mol^{-1}$
$M^{2+}(g) \rightarrow M^{3+}(g) + e^-$	$\Delta H = 3000\,kJ\,mol^{-1}$

[6 marks]

Answer: .....



.....

.....

Required value is 2 × 3000 + 3000 – 2000 – 7000 – 1000 = **– 1000 kJ mol^{-1}**.....

Q# 239/

Q42	B

Q# 240/

Q44	G

Q# 241/ Cambridge/2022/Section 2/ www.SmashingScience.org

Q47	E

Q# 242/

Q42	B

Q# 243/

Q44	G

Q# 244/

Q47	E

Q# 245/ Cambridge/2021/Section 1 www.SmashingScience.org

Q57	C

Q# 246/ Cambridge/2020sp (2020sp (Specimen) Paper)/Section 1 www.SmashingScience.org

42	A

42

The answer is option **A**.

Aqueous sodium chloride contains two cations (Na^+ and H^+) and two anions (Cl^- and OH^-).

The positive electrode (anode) attracts anions and the negative electrode (cathode) attracts cations.

When two ions are attracted to an electrode, only one can be discharged as atoms. This is called preferential discharge.

In this case:

chlorine is discharged in preference to oxygen at the positive electrode (anode);

hydrogen is discharged in preference to sodium at the negative electrode (cathode).

Q# 247/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q48	A

Q# 248/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q59	F

Q# 249/ Cambridge/2020/Section 1 www.SmashingScience.org

Q48	A	CHEM

Q# 250/ Cambridge/2020/Section 1 www.SmashingScience.org

Q59	F	CHEM

Q# 251/ Cambridge/2019/Section 1 www.SmashingScience.org

46	D

Q# 252/ Cambridge/2019/Section 1 www.SmashingScience.org

54	E

Q# 253/ Cambridge/2018/Section 2/ www.SmashingScience.org

c) Determine the oxidation state of the metal atom or atoms in the following species.

(i) MnO_4^{2-}

[1 mark]

Answer: $-2 - (-2) \times 4 = +6$ [1]

(ii) $K_2Cr_2O_7$

[2 marks]

Answer: K: $+1$ [1]

Cr: $(-2 - (-2) \times 7) \div 2 = +6$ [1]

d) Write a balanced chemical equation in which Fe^{2+} is oxidised to Fe^{3+} by MnO_4^- in an **acidic aqueous solution** and in which the Mn is reduced to a species with oxidation state +2. Your equation must balance for both atoms and charge, and you may **not** use free electrons (e^-) to achieve this.

[4 marks]

Answer: $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$

$MnO_4^-(aq) + 5e^- + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l)$

$\Rightarrow 5Fe^{2+}(aq) + 8H^+(aq) + MnO_4^-(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$

[4] if all correct

If not, $5Fe^{2+} \rightarrow 5Fe^{3+}$ [1]

$MnO_4^- \rightarrow Mn^{2+}$ [1]

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39	A

Q# 255/ Cambridge/2017/Section 1 www.SmashingScience.org

45	D

Q# 256/ Cambridge/2017/Section 1 www.SmashingScience.org

50	B

Q# 257/ Cambridge/2016sp/Section 1 www.SmashingScience.org (Specimen Paper)

38 A

Q# 258/ Cambridge/2016/Section 1 www.SmashingScience.org

38	D

Q# 259/ Cambridge/2016/Section 1 www.SmashingScience.org

39	C

Q# 260/ Cambridge/2016/Section 1 www.SmashingScience.org

47	C

Q# 261/ Cambridge/2016/Section 1 www.SmashingScience.org

53	C

Q# 262/

Q# 263/

Q# 264/ Cambridge/2022sp/Section 2/ www.SmashingScience.org

20 C

20 The answer is option **C**.

	CH_3COOH	+	CH_3CH_2OH	⇌	$CH_3COOCH_2CH_3$	+	H_2O
mass at the start	120		92		0		18
M_r	60		46		88		18
number of moles at the start	2		2		0		1
number of moles at equilibrium	$2-x$		$2-x$		x		$1+x$

The equilibrium constant is: $K_c = \dfrac{[CH_3COOCH_2CH_3][H_2O]}{[CH_3COOH][CH_3CH_2OH]}$

Substituting in the number of moles: $K_c = \dfrac{(x)(1+x)}{(2-x)(2-x)} = 2$

Rearranging: $x^2 + x = 2(x^2 - 4x + 4)$

$x^2 + x = 2x^2 - 8x + 8$

$x^2 - 9x + 8 = 0$

Using the quadratic formula: $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \dfrac{-9 \pm \sqrt{9^2 - 32}}{2}$

or by factorising: $(x-8)(x-1) = 0$

$x = 8$ or 1

A value of 8 is impossible because that would require '–6 mol' of reactants.

At equilibrium there would be just one mole of ester, which has a mass of 88 g.

Q# 265/ Cambridge/2022/Section 2/ www.SmashingScience.org

Q48	F

Q# 266/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q28	D

Q# 267/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q35	B

Q# 268/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q54	G

Q# 269/ Cambridge/2019/Section 2/ www.SmashingScience.org

b) RMM of TFEA = 114. Mass of TFEA needed = 0.0700 x 114 = 7.98 g
1.489 g has a volume of 1 cm3. So 7.98 g has a volume of 7.98/1.489 = 5.36 cm^3. **[3]**

c) $CF_3COOH(aq) \rightleftharpoons CF_3COO^-(aq) + H^+(aq)$ **[1]**

d) $K_{eq} = [CF_3COO^-][H^+] / [CF_3COOH]$ **[2]**

e) $[CF_3COO^-] = [H^+] = 0.4119$ mol dm^{-3}.

$[CF_3COOH] = 0.700 - 0.4119 = 0.2881$ mol dm^{-3}.

K_{eq} = 0.4119^2 / 0.2881 = 0.589 **[3]**

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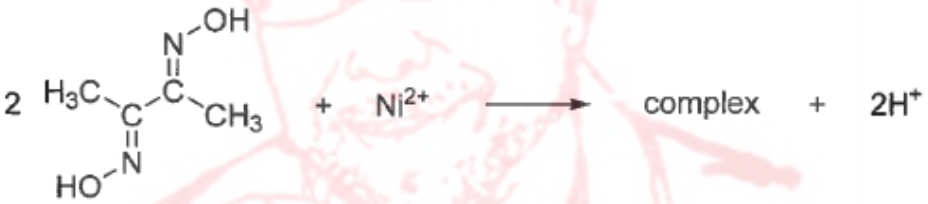
Mark Scheme Unavailable ☹

Q# 271/ Cambridge/2018/Section 2/ www.SmashingScience.org

c) Dimethylglyoxime reacts with Ni^{2+} ions in aqueous solution under mildly basic conditions to give a complex which is an insoluble red precipitate. The reaction involves two molecules of dimethylglyoxime and also results in the production of two H^+ ions.



dimethylglyoxime

Assuming that the above equation is balanced, determine the **molecular formula** of the complex and its relative molecular mass; a structural formula is **not** required.

(Relative atomic mass data is given in the Periodic Table on page 14.)

[4 marks]

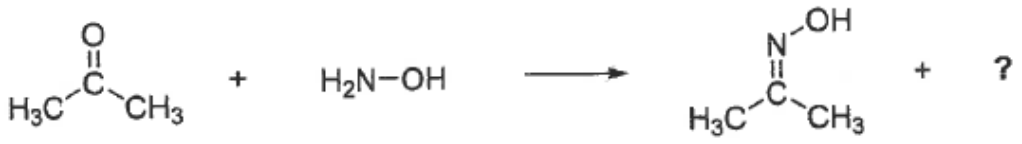
Answer: $Ni((C_4O_2N_2H_7)_2 = NiC_8O_4N_4H_{14}$ [2]

Mass = 288.922 [2]

Chemistry

Question C1

a) Ketones react with hydroxylamine, NH_2OH, to give oximes. An example of such a reaction involving the ketone propanone is shown below:



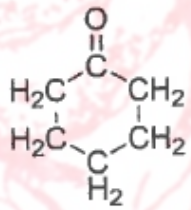
propanone (a ketone) — hydroxylamine — an oxime

(i) In addition to the oxime, this reaction produces a second product. Suggest what this molecule might be.

[1 mark]

Answer: H_2O or water [1]

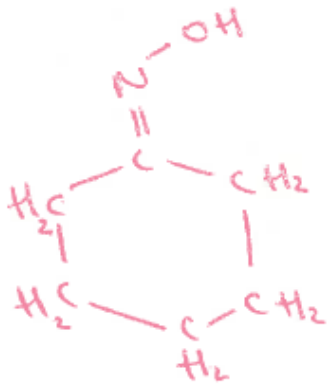
(ii) Draw the structure of the oxime that you would expect to be formed from the reaction of the ketone cyclohexanone with hydroxylamine.



cyclohexanone

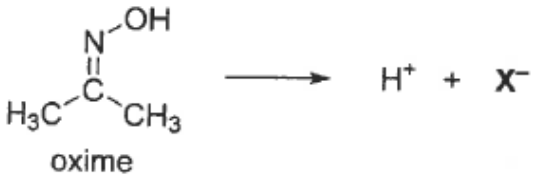
[2 marks]

Answer:



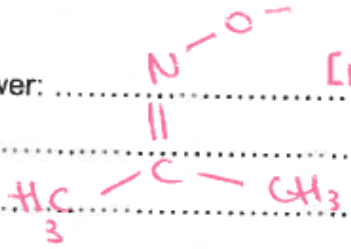
oxime = [1]
cycle = [1]

(iii) Oximes are weakly acidic. For the oxime below, explain which hydrogen atom will be the most acidic and draw the structure of the resulting anion X^-.

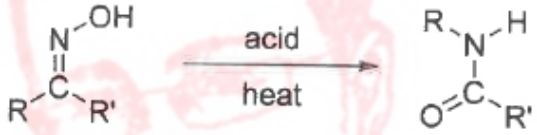


oxime

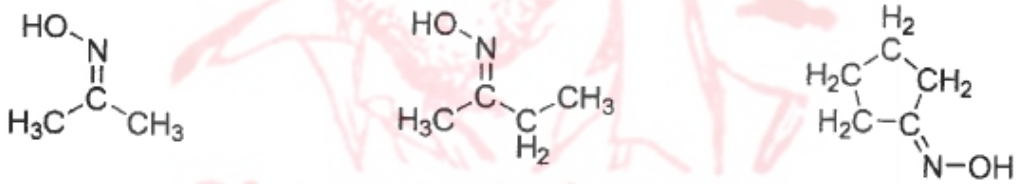
[3 marks]

Answer: 

b) Under acidic conditions, oximes undergo the following rearrangement reaction (note carefully that there are two different groups R and R').



Give the analogous structures into which each of the following oximes rearrange under the same conditions.



[4 marks]

Answer:

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Q49	D	CHEM

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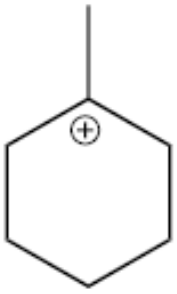
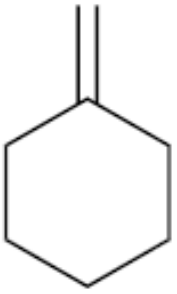
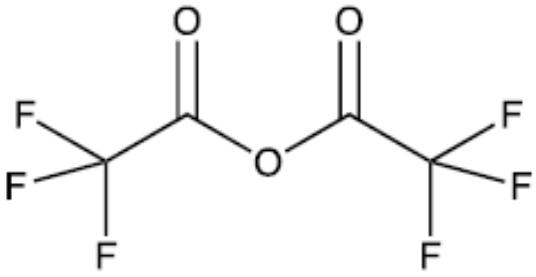
f) addition **[1]**

g)  **[1]**

h)  **[1]**

i)  **[1]**

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18 E

18 The answer is option **E**.

Compound P must have a C=C bond somewhere in its structure, and Q is a bromoalkane.

Alcohols are formed when bromoalkanes undergo substitution reactions with aqueous sodium hydroxide.

When completely oxidised by acidified potassium dichromate(VI), primary alcohols form carboxylic acids which do react with aqueous sodium carbonate.

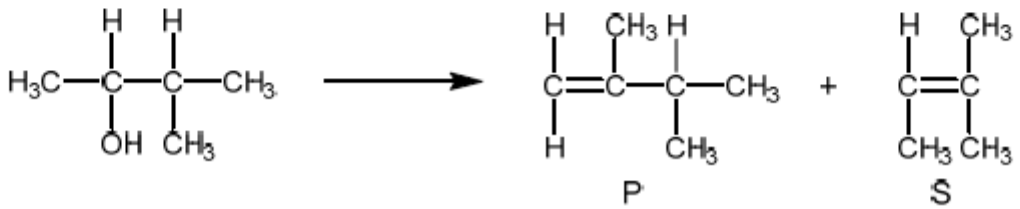
Secondary alcohols are oxidised to ketones which do not react with aqueous sodium carbonate and tertiary alcohols cannot be oxidised by acidified potassium dichromate(VI). Therefore R must be a secondary alcohol.

Pent-1-ene is incorrect as it would form 2-bromopentane as the only major product with HBr, which would then form pentan-2-ol. This would be dehydrated to form pent-2-ene as the other alkene, S. This does have stereoisomers.

Pent-2-ene is incorrect as there would be two products in significant quantity formed in the reaction with HBr: 2-bromopentane and 3-bromopentane (both formed from secondary carbocations).

The correct answer must therefore be one of the branched alkenes. If P were either 2-methylbut-1-ene or 2-methylbut-2-ene, because the double bond is adjacent to the branch in the chain, a tertiary bromoalkane would be formed as the major product. After the substitution reaction, this bromoalkane would become a tertiary alcohol, which cannot be oxidised by acidified potassium dichromate(VI).

3-methylbut-1-ene must therefore be the correct answer. This alkene would firstly form 2-bromo-3-methylbutane as the only major product with HBr and then 2-methylbutan-2-ol. This alcohol would be dehydrated to form 2-methylbut-2-ene as alkene S, which has two methyl groups attached to one end of the carbon double bond, and therefore does not have stereoisomers.



Q# 276/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q25	D

Q# 277/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q26	B

Q# 278/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q29	D

Q# 279/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q36	E

Q# 280/ Cambridge/2021/Section 2/ www.SmashingScience.org

Q38	H

Q# 281/ Cambridge/2022/Section 2/ www.SmashingScience.org

Q51	C

Q# 282/ Cambridge/2020/Section 2/ www.SmashingScience.org

Q49	D

Q# 283/ Cambridge/2019/Section 1 www.SmashingScience.org

39	E

Q# 284/ Cambridge/2018/Section 1 www.SmashingScience.org

49	B

Q# 285/ Cambridge/2017/Section 1 www.SmashingScience.org

41	D

Q# 286/ Cambridge/2016/Section 1 www.SmashingScience.org

43	D

NSAA Natural Science Admissions Assessment Syllabus mapped to CAIE A Level Chemistry

NSAA Topic	CAIE Topic	NSAA Topic Details
C1. Atomic structure	T1 Atomic structure	C1.1 Describe the structure of the atom as a central nucleus (containing protons and neutrons) surrounded by electrons moving in shells/energy levels. C1.2 Know the relative masses and charges of protons, neutrons and electrons, and recognise that most of the mass of an atom is in the nucleus. C1.3 Know and be able to use the terms *atomic number* and *mass number*, together with standard notation (e.g. ^{12}C), and so be able to calculate the number of protons, neutrons and electrons in any atom or ion. C1.4 Use the atomic number to write the electron configurations of the first 20 elements in the Periodic Table (H to Ca) in comma-separated format (e.g. 2,8,8,1 for a potassium atom). C1.5 Know the definition of isotopes as atoms of an element with the same number of protons but different numbers of neutrons (so having different mass numbers). Use data, including that from a mass spectrometer, to identify the number and abundances of different isotopes of elements. C1.6 Know and use the concept of relative atomic mass, A_r, including calculating values from given data.
C2. The Periodic Table (IUPAC conventions, Groups are labelled as 1-18)	T9 The periodic table	C2.1 Know that Periods are horizontal rows and Groups are vertical columns. C2.2 Know that the elements are arranged in the order of increasing atomic number. C2.3 Recall the position of metals and non-metals in the Periodic Table: alkali metals (Group 1), alkaline earth metals (Group 2), common non-metals in Group 16, the halogens (Group 17), the noble gases (Group 18) and the transition metals. C2.4 Know and use the relationship between the position of an atom in the Periodic Table (Group and Period) and the electron configuration of the atom. C2.5 Understand that elements in the same Group have similar chemical properties and that down a metal Group, reactivity increases and down a non-metal Group, reactivity decreases.
C3. Chemical reactions, formulae and equations	T2 Atoms, molecules and stoichiometry T7 Equilibria	C3.1 Understand that in a chemical reaction, new substances are formed by the rearrangement of atoms and their electrons, but no nuclei are destroyed or created. C3.2 Know the chemical formulae of simple, common

NSAA Topic	CAIE Topic	NSAA Topic Details
		ionic and covalent compounds. C3.3 Know and use state symbols: solid (s), liquid (l), gas (g), aqueous solution (aq). C3.4 Be able to construct and balance a chemical equation, including ionic and half-equations. C3.5 Understand that often chemical reactions can be reversible and do not go to completion. All of the reactants do not turn fully into the products but the reaction reaches a state of equilibrium in a closed system. a. Know the factors that can affect the position of an equilibrium (concentration of reactants/products, temperature, overall pressure). b. Predict the effect of changing these factors on the position of equilibrium.
C4. Quantitative chemistry	T2 Atoms, molecules and stoichiometry	C4.1 Use A_r values to calculate the relative molar mass, M_r. C4.2 Know that Avogadro's number gives the number of particles in one mole of a substance. C4.3 Know that one mole of a substance is the A_r or M_r in grams, and perform conversions of grams to moles and *vice versa* (including working in tonnes and kilograms). Know that the amount of a substance corresponds to the number of moles of a substance. C4.4 Calculate the percentage composition by mass of a compound using given A_r values. C4.5 Know that the *empirical formula* is the simplest integer ratio of atoms in a compound. Find the empirical formula of a compound from a variety of data, such as the percentage composition by mass of the elements present or reacting masses. Find the molecular formula from the empirical formula if given the M_r value. C4.6 Use balanced chemical equations to calculate the masses of reactants and products, including if there is a limiting reactant present. C4.7 Be able to construct balanced chemical equations from reacting masses or gas volumes data. C4.8 Understand that (for an ideal gas) one mole of a gas occupies a set volume at a given temperature and pressure (for example, 24 dm^3 at room temperature and pressure (rtp)), and perform conversions of volumes to number of moles, and *vice versa*. C4.9 Solutions: a. Understand that concentration can be measured in mol dm^{-3} or g dm^{-3}, and be able to calculate the concentration given the number of moles (or mass) of solute and the volume of solution.

NSAA Topic	CAIE Topic	NSAA Topic Details
		b. Know the term *saturated solution*, be able to calculate solubility and interpret solubility data. C4.10 Use the concentrations of solutions (or find the concentrations from given data) and the reacting ratio of reactants from the balanced equation to perform titration calculations. C4.11 Calculate the percentage yield of a reaction using the balanced chemical equation and the equation: percentage yield = $\frac{\text{actual yield (g)}}{\text{predicted yield (g)}} \times 100$
C5. Oxidation, reduction and redox	T6 Electrochemistry	C5.1 Know that on a basic level, oxidation is the gain of oxygen and that reduction is the removal of oxygen. C5.2 Know and be able to use the concept that oxidation and reduction are the transfer of electrons, i.e. reduction is the gain of electrons and oxidation is the loss of electrons. C5.3 Determine and use the oxidation states of atoms in simple inorganic compounds. C5.4 Identify any chemical equation that involves: oxidation only, reduction only, redox (both oxidation and reduction taking place), or no oxidation/reduction. C5.5 Understand the concept of *disproportionation* and recognise reactions (or species) where this occurs. C5.6 Understand the terms *oxidising agent* and *reducing agent*, and be able to identify them in reactions.
C6. Chemical bonding, structure and properties	T3 Chemical bonding	C6.1 Define and understand the differences between elements, compounds and mixtures. C6.2 Understand that atoms often react to form compounds which have the electron configuration of a noble gas (Group 18). Understand that the type of bonding taking place depends on the atoms involved in the reaction. C6.3 Ionic bonding: a. Know that ions are formed by transfer of electrons from atoms of metals to atoms of non-metals, and that these ions (of opposite charge) attract to form ionic compounds. b. Predict the charge of the most stable ions formed from elements in Groups 1, 2, 16 and 17 and aluminium by consideration of their electron configuration. c. Know the chemical formulae of common compound ions, e.g. CO_3^{2-} and OH^-.

NSAA Topic	CAIE Topic	NSAA Topic Details
		d. Know that when an element can exist in more than one oxidation state, e.g. Cu, Fe, then Roman numerals are used to denote the one present, e.g. iron(III) chloride for $FeCl_3$. e. Determine the formulae of ionic compounds from their constituent ions. f. Understand the general physical properties of ionic compounds, such as melting point and conductivity. C6.4 Covalent bonding: a. Know that a covalent bond is formed when atoms share one (or more) pair(s) of electrons, generally between non-metals. b. Understand that covalently bonded substances can be small molecules (e.g. water, ammonia, methane) or giant structures (e.g. diamond, graphite, silicon dioxide). c. Understand the general physical properties of substances composed of small molecules or of those that exist as giant covalent structures. C6.5 Metallic bonding: a. Understand that solid metals exist as a giant structure of positively charged ions surrounded by delocalised (free) electrons. b. Understand the general physical properties of metals, such as melting point and conductivity. C6.6 Understand that intermolecular forces can exist between molecules, and that these forces must be overcome in melting and boiling. C6.7 Be able to relate structure and bonding to physical properties, such as melting point and conductivity.
C7. Group chemistry	T9 The periodic table T11 Group 17	C7.1 Know the physical and chemical properties of the alkali metals (Group 1), the halogens (Group 17) and the noble gases (Group 18). C7.2 Describe the trends in chemical reactivity and physical properties of the alkali metals (Group 1) and make predictions based on those trends. This includes knowledge of the relative positions of lithium, sodium and potassium in Group 1. C7.3 The halogens (Group 17): a. Describe the trends in chemical reactivity and physical properties of the halogens and make predictions based on those trends. This includes knowledge of the relative positions of fluorine, chlorine, bromine and iodine in Group 17. b. Explain what is meant by a displacement reaction, in terms of reactivity competition, between halogens and halide ions.

NSAA Topic	CAIE Topic	NSAA Topic Details
C8. Separation techniques	T37 Analytical techniques	C8.1 Know that chemical processes are required to displace constituent elements from their compounds. C8.2 Know that physical processes are required to separate mixtures, including miscible/immiscible liquids and dissolved/insoluble solids. C8.3 Know when to apply the following separation techniques: simple/fractional distillation, paper chromatography (including use of R_f values), use of a separating funnel, centrifugation, dissolving, filtration, evaporation and crystallisation. C8.4 Know how to establish the purity of a substance using chromatography.
C9. Acids, bases and salts	T7 Equilibria	C9.1 Acids: a. Define an acid as a substance that can form $H^+(aq)$ ions or that is an H^+ donor. b. Describe reactions with metals, carbonates, metal hydroxides and metal oxides in which salts are formed. c. Understand the terms *strong*, *weak*, *dilute* and *concentrated*. d. Know that some oxides of non-metals react with water to form acidic solutions. e. Recall that pH is a measure of H^+ ion concentration, and recall that a change of 1 on the pH scale corresponds to a change by a factor of 10 in H^+ ion concentration. f. Know that one mole of some acidic substances is able to form/donate more than one mole of H^+ ions, including the use of the terms *mono-*, *di-*, *tri-*, and *polyprotic*. C9.2 Bases: a. Define a base as a substance that can form $OH^-(aq)$ ions or that is an H^+ acceptor. b. Understand the terms *strong*, *weak*, *dilute* and *concentrated*. c. Know that some oxides and hydroxides of metals react with water to form alkaline solutions. C9.3 Know that the reaction of an acid with a base can lead to neutralisation and is often exothermic.
C10. Rates of reaction	5 Chemical energetics	C10.1 Describe the qualitative effects on a rate of reaction of concentration, temperature, particle size, a catalyst and, for gases, pressure. C10.2 Know that the rate of reaction can be found by measuring the loss of a reactant or the gain of a product, or by measurement of a physical property over time, and be able to identify which of these measurements can be used in a given situation.

NSAA Topic	CAIE Topic	NSAA Topic Details
		C10.3 Interpret data in graphical form concerning the rate of a reaction. C10.4 Use collision theory to explain changes in the rate of a reaction. C10.5 Understand that particles must have sufficient energy when they collide to react, and that this energy is called the activation energy (E_a). Identify the activation energy on an energy level diagram. C10.6 Know that catalysts: a. are not used up in a reaction. b. are chemically unchanged at the end of a reaction. c. provide an alternative route (reaction mechanism) with a lower activation energy, and interpret this effect on an energy level diagram. d. do not affect the position of an equilibrium. e. C11. Energetics C11.1 Understand the concepts of an exothermic reaction, for which ΔH is negative (negative enthalpy change), and an endothermic reaction, for which ΔH is positive (positive enthalpy change). C11.2 Know that if a reversible reaction is exothermic in one direction, it is endothermic in the other direction. C11.3 Be able to interpret energy level diagrams. C11.4 Be able to calculate energy changes from specific heat capacities and changes in temperature in calorimetry experiments. C11.5 Know that bond breaking is endothermic and bond formation is exothermic, and be able to use bond energy data to calculate energy changes.
C12. Electrolysis	T24 Electrochemistry	C12.1 Understand the terms *electrode, cathode (negative electrode), anode (positive electrode)* and *electrolyte*. C12.2 Understand why direct current (dc), and not alternating current (ac), is used in electrolysis. C12.3 Understand that in electrolysis at the cathode, the cations (positively charged ions) receive electrons (reduction) to change into atoms or molecules, and at the anode, the anions (negatively charged ions) lose electrons to form atoms or molecules (oxidation). C12.4 Understand and be able to predict the products of the electrolysis of the following:

NSAA Topic	CAIE Topic	NSAA Topic Details
		a. aqueous solutions (including those of salts), including situations where more than one ion/molecule is attracted to a single electrode b. molten binary compounds C12.5 Be able to write half-equations for the processes taking place at each electrode. C12.6 Explain how electrolysis is used to electroplate objects.
C13. Carbon/Organic chemistry	T13 An introduction to AS Level organic chemistry	C13.1 General concepts: a. Know that crude oil is the main source of hydrocarbons and that it is separated into fractions by fractional distillation (names and uses of specific fractions not expected). b. Understand the link between carbon chain length and the following trends in physical properties of hydrocarbons: boiling points, viscosity, flammability. c. Know the use of longer chain alkanes in cracking to form shorter chain alkanes and alkenes, and be able to write balanced chemical equations for these reactions. d. Understand structural isomerism and be able to recognise examples. e. Understand and be able to use the following terms: *molecular formula,* *full structural formula (displayed structure)* and *condensed structural formula*. f. Understand and be able to use the terms *complete combustion* and *incomplete combustion*, and be able to write balanced chemical equations for such reactions. g. Know the IUPAC guidelines for the systematic naming of carbon compounds, and apply the guidelines in order to be able to name all the compounds in this section of the specification. h. Know and understand the terms *homologous series* and *functional group*.
C13. Carbon/Organic chemistry	T14 Hydrocarbons	C13.2 Alkanes (saturated hydrocarbons): a. Describe alkanes as a homologous series with the general formula of C_nH_{2n+2}. b. Be able to name, or recognise from the name, the C1 to C6 straight-chain alkanes. C13.3 Alkenes (unsaturated hydrocarbons):

NSAA Topic	CAIE Topic	NSAA Topic Details
		a. Describe alkenes as a homologous series with a double bond and the general formula C_nH_{2n}. b. Be able to name, or recognise from the name, C2 to C6 straight-chain alkenes, including the position of the double bond. c. Recognise and be able to use the test for unsaturation with bromine water. d. Know that addition reactions take place with the following substances: hydrogen, halogens, hydrogen halides and steam. Be able to write the balanced chemical equations for these reactions and recognise the formulae of the products formed. (Mechanisms and consideration of carbocation stability are **not** required.)
C13. Carbon/Organic chemistry	T20 Polymerisation T35 Polymerisation	C13.4 Polymers: a. Addition polymerisation, polyalkenes: i. Know that alkenes or other molecules with a C=C bond may react with each other to form long-chain saturated molecules called polymers by addition reactions called polymerisation, and that the unsaturated molecules are called monomers. ii. If given an unsaturated monomer molecule, be able to recognise the structure of the polymer and *vice versa*. iii. Be able to recognise the repeating unit of these polymers. b. Condensation polymerisation, polyesters and polyamides (to include amino acids forming proteins): i. If given the monomer molecules, be able to recognise the structure of the polymer and *vice versa*. ii. Be able to recognise the repeating unit of these polymers. c. Understand the terms *biodegradable* and *non-biodegradable* when applied to polymers.
C13. Carbon/Organic chemistry	T16 Hydroxy compounds	C13.5 Alcohols: a. Describe alcohols as a homologous series with the general formula $C_nH_{2n+1}OH$. b. Be able to name, or recognise from the name, C1 to C6 straight-chain alcohols, including the position of the -OH group. c. Describe the reaction of alcohols with sodium metal.

NSAA Topic	CAIE Topic	NSAA Topic Details
C13. Carbon/Organic chemistry	T17 Carbonyl compounds	C13.6 Carboxylic acids: a. Describe carboxylic acids as a homologous series with the general formula $C_nH_{2n+1}COOH$. b. Be able to name, or recognise from the name, C1 to C6 straight-chain carboxylic acids. c. Describe the chemical properties of carboxylic acids as those of weak acids, and so be able to predict their reactions and determine the formulae of their salts. d. Know that carboxylic acids react with alcohols in the presence of an acid catalyst to produce esters.
C14. Metals	iGCSE Topic 9 Metals A Level T28 is not a good match (nothing on extraction, too much on d orbitals)	C14.1 Understand that the reactivity of a metal is linked to its tendency to form positive ions and the ease of extraction of the metal. C14.2 Be able to use displacement reactions to establish the order of reactivity of metals and *vice versa*. C14.3 Describe how the uses of metals are related to their physical and chemical properties, e.g. Al, Fe, Cu, Ag, Au, Ti, and understand that alloys can be formed to produce materials with specific properties. C14.4 Know that most metal ores are the oxides of the metal, and that the extraction of metals always involves reduction processes. C14.5 Know that common properties of transition metals include: a. they are able to form stable ions in different oxidation states b. they often form coloured compounds c. they are often used as catalysts (as ions or atoms)
C15. Kinetic/Particle theory	T8 Reaction kinetics	C15.1 Be able to describe the packing and movement of particles in the three states of matter: solid, liquid and gas. C15.2 Understand the changes to the packing and movement of particles in the following changes of state: freezing, melting, boiling/evaporating, and condensing. Understand that the energy required for these processes is related to the bonding and structure of the substance, including a consideration of intermolecular forces.
C16. Chemical tests	iGCSE Topic 12 (no direct topic present at AS or A2, but these tests are required for Paper 3)	C16.1 Know and recognise the following tests for gases: a. hydrogen – explodes with a 'squeaky pop' when a burning splint is held at the open end of a test tube b. oxygen – relights a glowing splint c. carbon dioxide – limewater turns cloudy when shaken with the gas

NSAA Topic	CAIE Topic	NSAA Topic Details
		d. chlorine – damp blue litmus paper turns red and then is bleached (paper turns white) C16.2 Know, recognise and describe the following tests for the anions: a. carbonates – using a dilute acid b. halides – using an aqueous solution of silver nitrate in the presence of dilute nitric acid (chlorides form a white precipitate; bromides form a cream precipitate; iodides form a yellow precipitate) c. sulfates – using an aqueous solution of barium chloride in the presence of dilute hydrochloric acid C16.3 Know and recognise the test for the following metal cations using aqueous sodium hydroxide: a. Al^{3+}, Ca^{2+} and Mg^{2+} each form a white precipitate. b. Cu^{2+} forms a blue precipitate. c. Fe^{2+} forms a green precipitate. d. Fe^{3+} forms a brown precipitate. C16.4 Recall and recognise the flame test for the cations of the following metals: Li (crimson red), Na (yellow-orange), K (lilac), Ca (red-orange), Cu (green) C16.5 Know and recognise the test for the presence of water using anhydrous copper(II) sulfate (colour change from white to blue).
C17. Air and water	iGCSE Topic 10 Chemistry and the environment	C17.1 Know and be able to use the composition of dry air, and understand that fractional distillation can be used to separate the components of air. C17.2 Know the origins and describe the effects of greenhouse gases such as CO_2 and CH_4. C17.3 Know the origins and effects of gaseous pollutants such as CO, CO_2, SO_2 and NO_x. C17.4 Know the purpose of chlorine and fluoride ions in the treatment of drinking water.