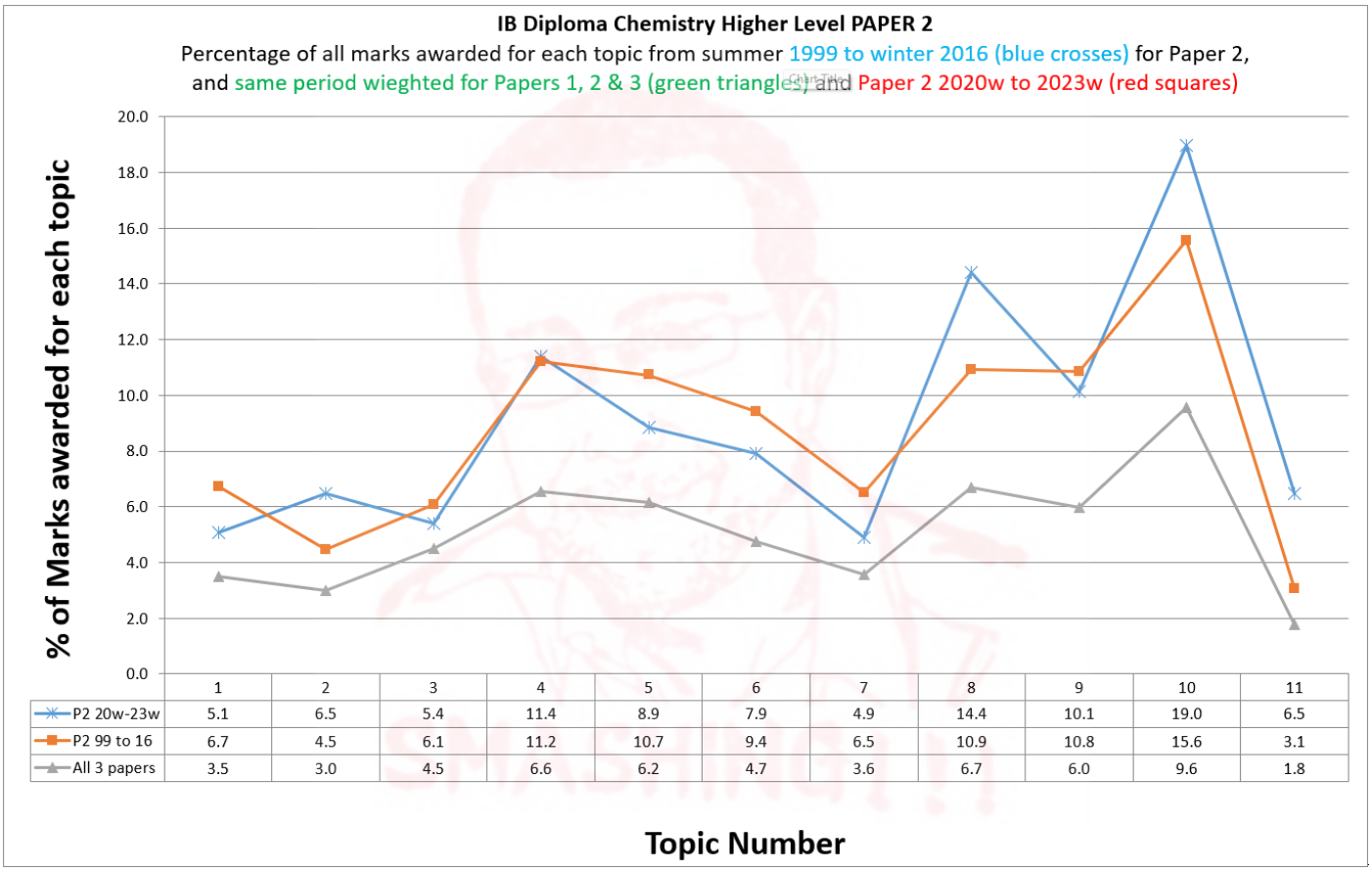
IB Chemistry Higher Level Paper 2 Past Exam Questions by Topic 2020w to 2023w (7 Papers)

Topic Chem 2 Atomic structure

For a digital version of this document scan the code below, or go here:
https://www.smashingscience.org/ib-chemistry-hl-sl

A note on the topic numbers used here:

IB Chemistry topic numbers from 12 onwards have been merged with their SL counterparts, so "Topic 3" in this booklet includes marks for both IB Chemistry Topic 3 (Periodicity) and Topic 13 (The periodic table—the transition metals). For more information see the syllabus ("Chemistry Guide: First Assessment 2016"). For exams in 2025 and later changes to the ordering of the syllabus have been made which are not addressed here.



	1	2	3	4	5	6	7	8	9	10	11
P2 20w-23w	5.1	6.5	5.4	11.4	8.9	7.9	4.9	14.4	10.1	19.0	6.5
P2 99 to 16	6.7	4.5	6.1	11.2	10.7	9.4	6.5	10.9	10.8	15.6	3.1
All 3 papers	3.5	3.0	4.5	6.6	6.2	4.7	3.6	6.7	6.0	9.6	1.8

Topic **Chem Q# 1/** IB Chem/**2020/s**/TZ1/Paper 2/Higher Level/Q1. www.SmashingScience.org :o)
Entire exam paper was not published

Topic Chem 2 Atomic structure Q# 11/ IB Chem/2023/w/TZ0/Paper 2/Higher Level/Q5. www.SmashingScience.org :o)

5. Beryllium is a low-density metal that is used in specialized lightweight alloys.

(h) Outline how the first ionization energy of beryllium could be found from its atomic emission spectrum. [1]

. . . . . .

. . . . . .

4. Carbon disulfide, CS_2, undergoes gas phase hydrolysis according to the overall equation

$$CS_2(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 2H_2S(g)$$

(c) Sulfur has a number of natural isotopes and a sample of sulfur was enriched in $^{36}_{16}S$, to produce a mixture with the following composition:

Isotope	Percent
$^{32}_{16}S$	90 %
$^{33}_{16}S$	1 %
$^{34}_{16}S$	4 %
$^{36}_{16}S$	5 %

(i) Calculate the relative atomic mass of this enriched sample, correct to two decimal places. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(ii) In naturally occurring sulfur, the relative abundance of $^{36}_{16}S$ is only 0.0100 %. Calculate the number of atoms of this isotope that would be present in 1.00 g of natural sulfur. Use sections 2 and 6 of the data booklet. [2]

. . . . . .

. . . . . .

. . . . . .

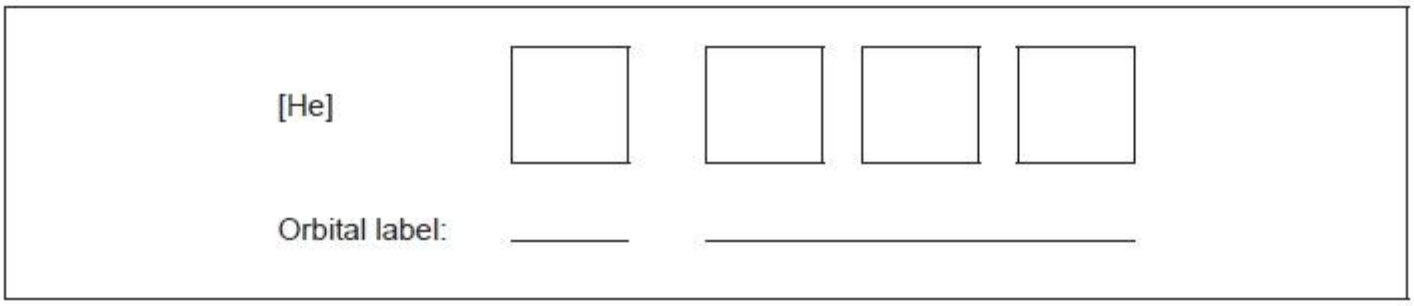
. . . . . .

. . . . . .

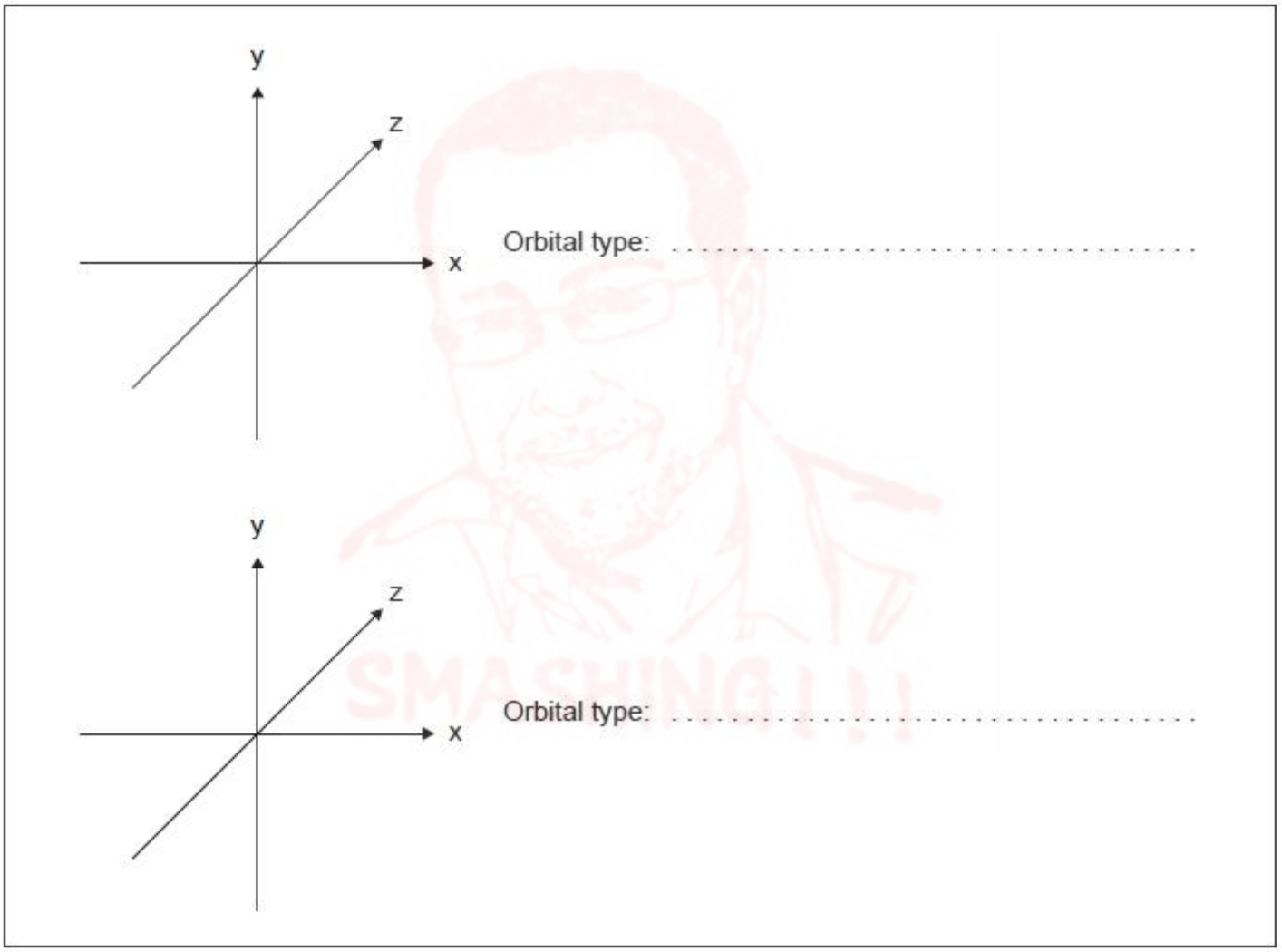
. . . . . .

2. The periodic table is a useful tool in explaining trends of chemical behaviour.

(a) (i) Annotate and label the ground state orbital diagram of boron, using arrows to represent electrons. [1]



(ii) Sketch the shapes of the occupied orbitals identified in part (a)(i). [2]



3. Consider the following reaction:

$$Cu^{2+}(aq) + Fe(s) \rightarrow Fe^{2+}(aq) + Cu(s)$$

(a) State the ground-state electron configuration for Fe^{2+}. [1]

. . . . . .

. . . . . .

(c) Predict, with a reason, whether Cu or Cu^{2+} has the greater ionization energy. [1]

. . . . . .

. . . . . .

. . . . . .

(d) Determine the frequency, in s^{-1}, of a photon that will cause the first ionization of copper. Use sections 1, 2 and 8 of the data booklet. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(e) Outline the magnetic properties of iron by referring to its electron configuration. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

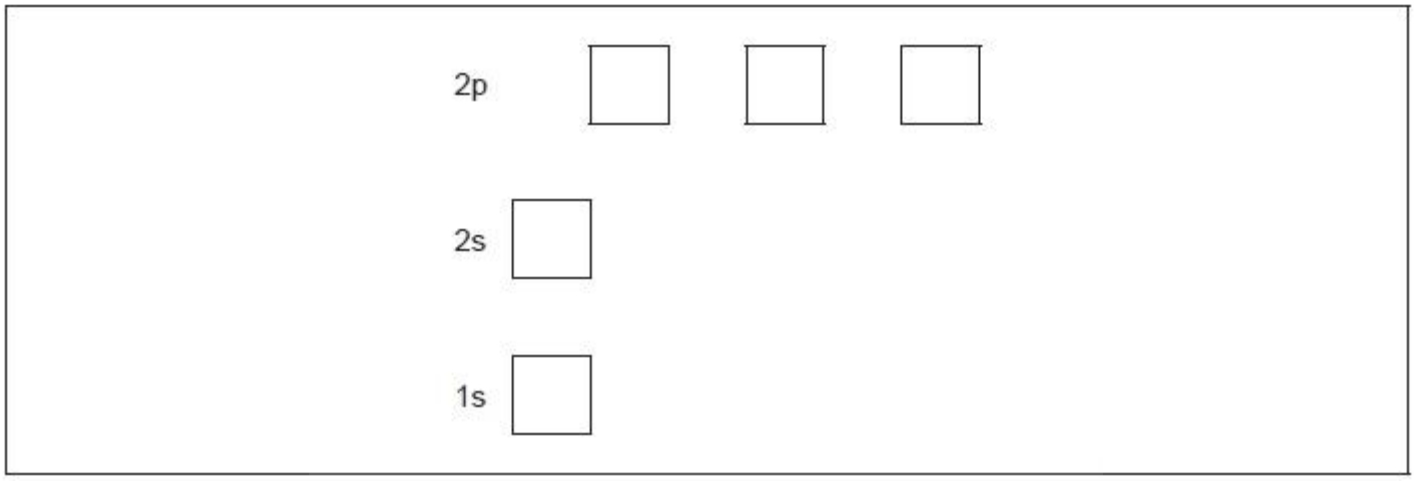
(ii) This reaction can be done with a copper catalyst. State the ground-state electron configuration for copper. [1]

. . . . . .

. . . . . .

6. Nitric acid is usually produced by the oxidation of ammonia.

(a) (i) Draw arrows in the boxes to represent the electron configuration of a nitrogen atom. [1]



(e) Most nitride ions are $^{14}N^{3-}$.

(i) State the number of subatomic particles in this ion. [1]

Protons: .....

Neutrons: .....

Electrons: .....

(ii) Some nitride ions are $^{15}N^{3-}$. State the term that describes the relationship between $^{14}N^{3-}$ and $^{15}N^{3-}$. [1]

.....

(iii) The nitride ion and the magnesium ion are isoelectronic (they have the same electron configuration). Determine, giving a reason, which has the greater ionic radius. [1]

.....

.....

(iv) Suggest, giving a reason, whether magnesium or nitrogen would have the greater sixth ionization energy. [1]

.....

.....

.....

.....

(f) Suggest **two** reasons why atoms are no longer regarded as the indivisible units of matter. [2]

.....

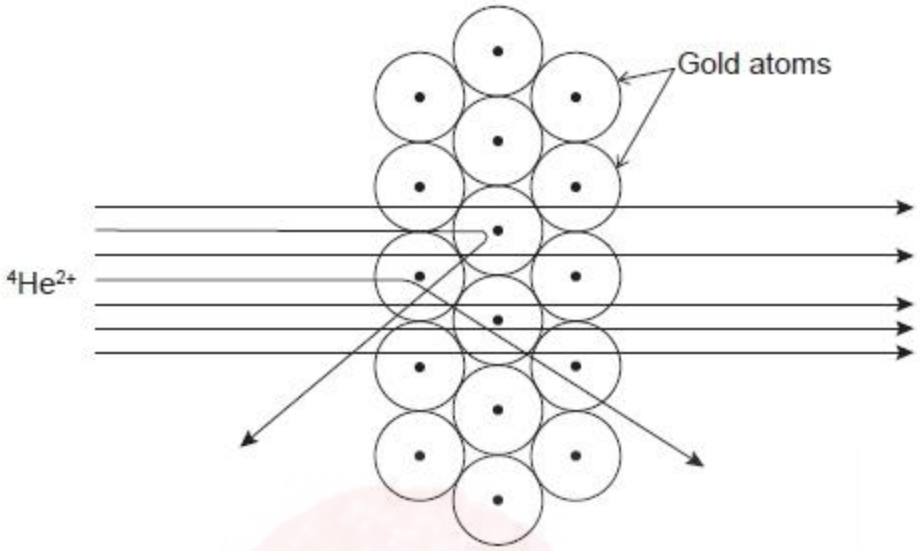
.....

.....

.....

.....

9. Fast moving helium nuclei ($^4He^{2+}$) were fired at a thin piece of gold foil with most passing undeflected but a few deviating largely from their path. The diagram illustrates this historic experiment.



(a) Suggest what can be concluded about the gold atom from this experiment. [2]

Most $^4He^{2+}$ passing straight through:

. . . . . .

. . . . . .

. . . . . .

Very few $^4He^{2+}$ deviating largely from their path:

. . . . . .

. . . . . .

. . . . . .

(b) (i) Subsequent experiments showed electrons existing in energy levels occupying various orbital shapes.

Draw diagrams of 1s, 2s and 2p. [2]

1s	2s	2p

(ii) State the electron configuration of copper. [1]

.....

.....

Topic **Chem 2 Q# 19/** IB Chem/2021/w/TZ0/Paper 2/Higher Level/Q2. www.SmashingScience.org :o)

2. Electron transitions are related to trends in the periodic table.

(b) Sodium emits yellow light with a frequency of 5.09×10^{14} Hz when electrons transition from 3p to 3s orbitals.

Calculate the energy difference, in J, between these two orbitals using sections 1 and 2 of the data booklet. [1]

.....

.....

.....

Topic **Chem 2 Q# 20/** IB Chem/2021/s/TZ1/Paper 2/Higher Level/Q3. www.SmashingScience.org :o)

3. Magnetite, Fe_3O_4, is another ore of iron that contains both Fe^{2+} and Fe^{3+}.

(b) Iron exists as several isotopes.

(i) State the type of spectroscopy that could be used to determine their relative abundances. [1]

. . . . . .

(ii) State the number of protons, neutrons and electrons in each species. [2]

	Protons	Neutrons	Electrons
$^{54}_{26}Fe$	. . . . .	. . . . .	. . . . .
$^{56}_{26}Fe^{3+}$	. . . . .	. . . . .	. . . . .

Topic **Chem 2 Q# 21/** IB Chem/2021/s/TZ1/Paper 2/Higher Level/Q1. www.SmashingScience.org :o)

Answer **all** questions. Answers must be written within the answer boxes provided.

1. Iron may be extracted from iron (II) sulfide, FeS.

(d) Iron (II) sulfide, FeS, is ionically bonded.

(iii) State the full electron configuration of the sulfide ion. [1]

. . . . . .

. . . . . .

(iv) Outline, in terms of their electronic structures, why the ionic radius of the sulfide ion is greater than that of the oxide ion. [1]

. . . . . .

. . . . . .

6. The electron configuration of copper makes it a useful metal.

(a) Determine the frequency of a photon that will cause the first ionization of copper. Use sections 1, 2 and 8 of the data booklet. [2]

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

Answer **all** questions. Answers must be written within the answer boxes provided.

1. Chlorine undergoes many reactions.

(a) (i) State the full electron configuration of the chlorine atom. [1]

. . . . . .

. . . . . .

(ii) State, giving a reason, whether the chlorine atom or the chloride ion has a larger radius. [1]

. . . . . .

. . . . . .

. . . . . .

(iii) Outline why the chlorine atom has a smaller atomic radius than the sulfur atom. [2]

. . . . . .

. . . . . .

. . . . . .

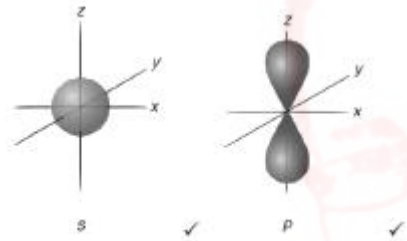
. . . . . .

5	h		frequency /wavelength of «the radiation at» convergence limit «is proportional to the ionization energy» ✓	*Accept highest frequency/shortest wavelength.*	1

Q# 12/ Chem 2 IB Chem/2023/w/TZ0/Paper 2/Higher Level/Q4. www.SmashingScience.org :o)

4	c	i	0.9x32 + 0.01x33 + 0.04x34 + 0.05x36 ✓ «A_r =» 32.29 ✓	*Award [2] for correct final answer.* *Do not accept 32.07 which is the data booklet value.* *M2 can only be awarded for answer with two decimal places.*	2
4	c	ii	amount of $^{36}_{16}S$ «= $\frac{0.0100}{100} \times \frac{1.00}{32.07}$ » = 3.12×10^{-6} «mol»✓ number of atoms «= 3.12×10^{-6} mol × 6.02×10^{23} mol^{-1}» = 1.88×10^{18} ✓	*Award [2] for correct final answer.*	2

Q# 13/ Chem 2 IB Chem/2023/s/TZ1/Paper 2/Higher Level/Q2. www.SmashingScience.org :o)

2.	(a)	(i)	 arrows *AND identifies 2s AND 2p sub orbitals* ✓	*Accept "hooks" to represent the electrons.*	1
2.	(a)	(ii)	 ✓ ✓	$P_{x,y}$ or $_z$ can be used. *M2 cannot be awarded if labels of orbital types are missing or incorrect* *Node of p orbital must be at the origin*	2

Q# 14/ Chem 2 IB Chem/2022/w/TZ0/Paper 2/Higher Level/Q3. www.SmashingScience.org :o)

3.	(a)		$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ *OR* $[Ar]3d^6$ ✓		1
3.	(c)		Cu^{2+} *AND* fewer shielding electrons/less electron-electron repulsion «from same nuclear charge» *OR* Cu^{2+} *AND* larger effective nuclear charge *OR* Cu^{2+} *AND* more energy required to remove electron from positive ion than neutral parent atom *OR* Cu^{2+} *AND* smaller radius *OR* Cu^{2+} *AND* electron is being lost from a lower energy/inner/3d orbital ✓		1

3.	(d)		*Alternative 1* «$E = 745\ kJ\ mol^{-1} \times \frac{1\ mol}{6.02 \times 10^{23} atoms} =$ » 1.24×10^{-21}«$kJ\ atom^{-1}$» ✓ «$E = h\nu$» «$1.24 \times 10^{-21} kJ \times \frac{1000\ J}{1\ kJ} = 6.63 \times 10^{-34} Js \times \nu$» «$\nu =$ » 1.87×10^{15}«s^{-1}» ✓ *Alternative 2* «$E=h\nu$» «$745 \times 10^3\ J\ mol^{-1} = 6.63 \times 10^{-34}\ J\ s \times \upsilon$ » «$\upsilon =$» 1.12×10^{39}«$s^{-1}\ mol^{-1}$» ✓ « $= \frac{1.12 \times 10^{39} s^{-1}}{6.02 \times 10^{23}}$» $= 1.87 \times 10^{16}$«s^{-1}» ✓	*Award [2] for correct final answer.*	2
3.	(e)		«iron atoms have 4» unpaired electrons ✓ aligns with a magnetic field/paramagnetic *OR* has a magnetic moment *OR* ferromagnetic ✓	*For M1 accept diagrams showing unpaired electrons.*	2

Q# 15/ Chem 2 IB Chem/2022/w/TZ0/Paper 2/Higher Level/Q2. www.SmashingScience.org :o)

2.	(e)	(ii)	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$ / $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$ *OR* $[Ar] 4s^1 3d^{10}$ / $[Ar] 3d^{10} 4s^1$ ✓		1

Q# 16/ Chem 2 IB Chem/2022/s/TZ1/Paper 2/Higher Level/Q6. www.SmashingScience.org :o)

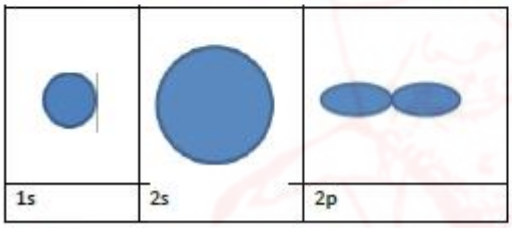
6.	a	i	2p ↑ ↑ ↑ 2s ↑↓ 1s ↑↓ ✓	*Accept all 2p electrons pointing downwards.* *Accept half arrows instead of full arrows.*	1

Q# 17/ Chem 2 IB Chem/2022/s/TZ1/Paper 2/Higher Level/Q1. www.SmashingScience.org :o)

1.	e	i	*Protons:* 7 ***AND*** *Neutrons:* 7 ***AND*** *Electrons:* 10 ✓		1
1.	e	ii	isotope«s» ✓		1
1.	e	iii	nitride ***AND*** smaller nuclear charge/number of protons/atomic number ✓		1
1.	e	iv	nitrogen ***AND*** electron lost from first *«energy»* level/s sub-level/s-orbital ***AND*** magnesium from p sub-level/p-orbital/second *«energy»* level *OR* nitrogen ***AND*** electron lost from lower level «than magnesium» ✓	*Accept "nitrogen **AND** electron lost closer to the nucleus «than magnesium»".*	1

1.	f		*Any two of:* subatomic particles «discovered» *OR* particles smaller/with masses less than atoms «discovered» *OR* «existence of» isotopes «same number of protons, different number of neutrons»✓ charged particles obtained from «neutral» atoms *OR* atoms can gain or lose electrons «and become charged» ✓ atom «discovered» to have structure ✓ fission *OR* atoms can be split ✓	*Accept atoms can undergo fusion «to produce heavier atoms».* *Accept specific examples of particles.* *Award [2] for "atom shown to have a nucleus with electrons around it" as both M1 and M3.*	2

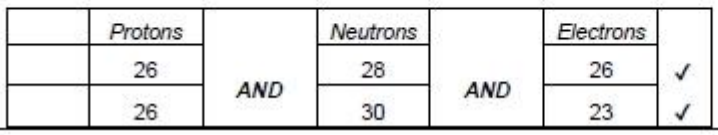
Q# 18/ Chem 2 IB Chem/2021/w/TZ0/Paper 2/Higher Level/Q9. www.SmashingScience.org :o)

9.	a		*Most $^4He^{2+}$ passing straight through:* most of the atom is empty space ***OR*** the space between nuclei is much larger than $^4He^{2+}$ particles ***OR*** nucleus/centre is «very» small «compared to the size of the atom» ✓ *Very few $^4He^{2+}$ deviating largely from their path:* nucleus/centre is positive «and repels $^4He^{2+}$ particles» ***OR*** nucleus/centre is «more» dense/heavy «than $^4He^{2+}$ particles and deflects them» ***OR*** nucleus/centre is «very» small «compared to the size of the atom» ✓	*Do **not** accept the same reason for both **M1** and **M2**.* *Accept "most of the atom is an electron cloud" for **M1**.* *Do **not** accept only "nucleus repels $^4He^{2+}$ particles" for **M2**.*	2
9.	b	i	 1s ***AND*** 2s as spheres ✓ one or more 2p orbital(s) as figure(s) of 8 shape(s) of any orientation (p_x, p_y p_z) ✓		2
9.	b	ii	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$ ***OR*** [Ar] $4s^1 3d^{10}$ ✓	*Accept configuration with 3d before 4s.*	1

Q# 19/ Chem 2 IB Chem/2021/w/TZ0/Paper 2/Higher Level/Q2. www.SmashingScience.org :o)

2.	b		«$\Delta E = h\nu = 6.63 \times 10^{-34}$ J s $\times$ 5.09×10^{14} s^{-1} =» 3.37×10^{-19} «J» ✓		1

Q# 20/ Chem 2 IB Chem/2021/s/TZ1/Paper 2/Higher Level/Q3. www.SmashingScience.org :o)

3.	b	i	mass «spectroscopy»/MS ✓		
3.	b	ii	 	*Award [1 max] for 4 correct values.*	2

Q# 21/ Chem 2 IB Chem/2021/s/TZ1/Paper 2/Higher Level/Q1. www.SmashingScience.org :o)

1.	d	iii	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ ✓	*Do not accept "[Ne] $3s^2\ 3p^6$".*	1
1.	d	iv	«valence» electrons further from nucleus/extra electron shell/ electrons in third/3s/3p level «not second/2s/2p»✓	*Accept 2,8 (for O^{2-}) and 2,8,8 (for S^{2-})*	1
1.	d	v	allows them to explain the properties of different compounds/substances *OR* enables them to generalise about substances *OR* enables them to make predictions ✓	*Accept other valid answers.*	1
1.	e	i	$4FeS(s) + 7O_2(g) \rightarrow 2Fe_2O_3(s) + 4SO_2(g)$ ✓	*Accept any correct ratio.*	1
1.	e	ii	+6 *OR* −2 to +4 ✓	*Accept "6/VI".* *Accept "−II, 4/+4/IV".* Do not accept 2- to 4+.	1
1.	e	iii	sulfur dioxide/SO_2 causes acid rain ✓	*Accept sulfur dioxide/SO_2/dust causes respiratory problems* *Do not accept just "causes respiratory problems" or "causes acid rain".*	1
1.	f		disrupts the regular arrangement «of iron atoms/ions» *OR* carbon different size «to iron atoms/ions» ✓ prevents layers/atoms sliding over each other ✓		2

Q# 22/ Chem 2 IB Chem/2020/w/TZ0/Paper 2/Higher Level/Q6. www.SmashingScience.org :o)

6.	a		«$E = \frac{745\,000\ J\ mol^{-1}}{6.02 \times 10^{23}\ mol^{-1}}$ =» 1.24×10^{-18} J ✓ «$E = hv$» «$1.24 \times 10^{-18}\ J = 6.63 \times 10^{-34}\ J\ s \times v$» $v = 1.87 \times 10^{15}$ «s^{-1}/Hz» ✓	*Award [2] for correct final answer.* *Award [1] for 1.12x10^{39} «Hz».*	2

Q# 23/ Chem 2 IB Chem/2020/w/TZ0/Paper 2/Higher Level/Q1. www.SmashingScience.org :o)

Question			Answers	Notes	Total
1.	a	i	$1s^2 2s^2 2p^6 3s^2 3p^5$ ✓	*Do not accept condensed electron configuration.*	1
1.	a	ii	Cl^- *AND* more «electron–electron» repulsion ✓	*Accept Cl^- AND has an extra electron.*	1
1.	a	iii	Cl has a greater nuclear charge/number of protons/Z_{eff} «causing a stronger pull on the outer electrons» ✓ same number of shells *OR* same «outer» energy level *OR* similar shielding ✓		2