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

Topic Chem 3 Periodicity

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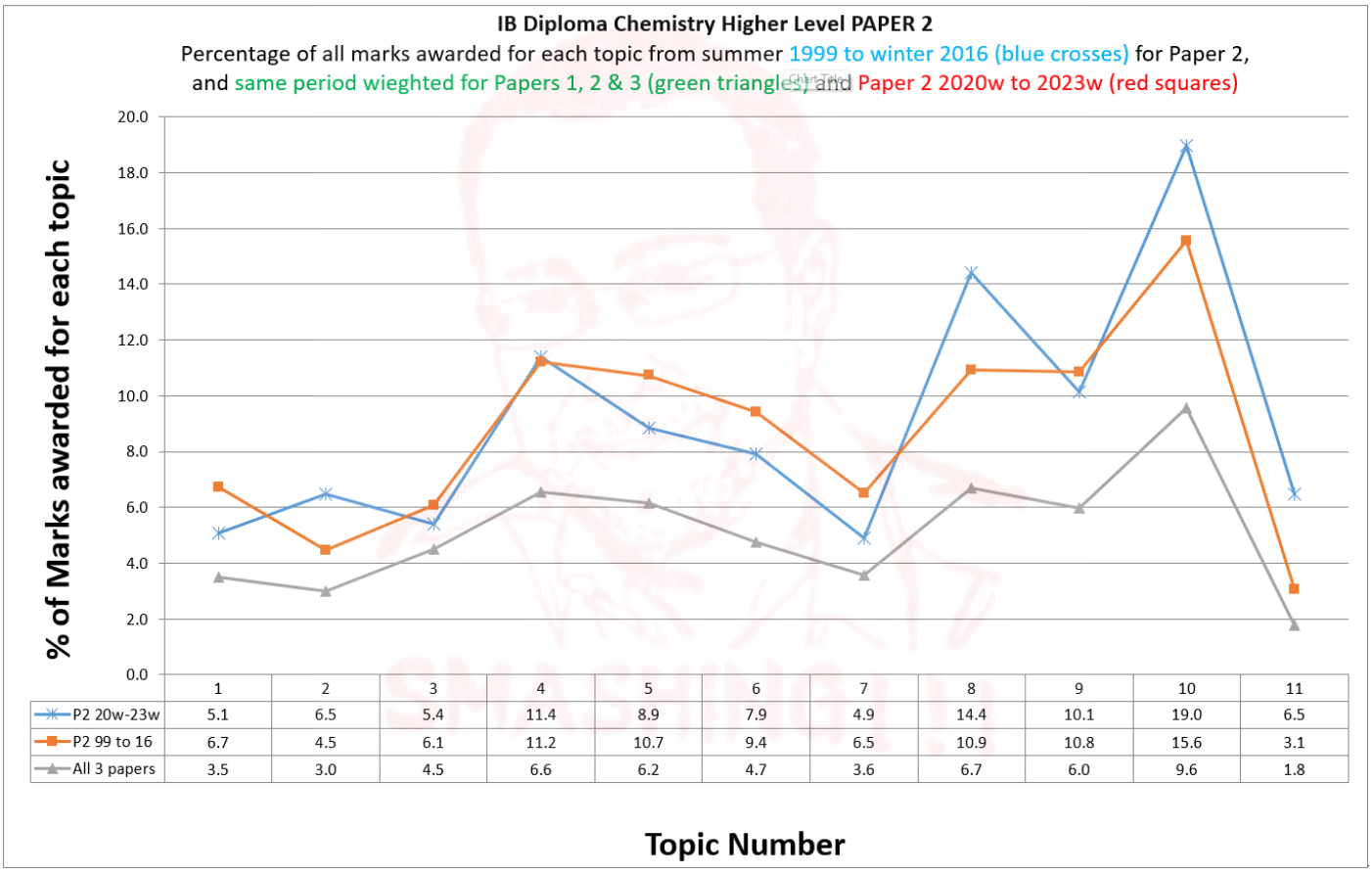
A note on the topic numbers used here:

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

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

(e) Iron (III) chloride also exists as a dimer in the vapour phase, but iron, unlike beryllium, is a transition element.

(i) Outline, in terms of its electronic structure, what identifies a transition element. [1]

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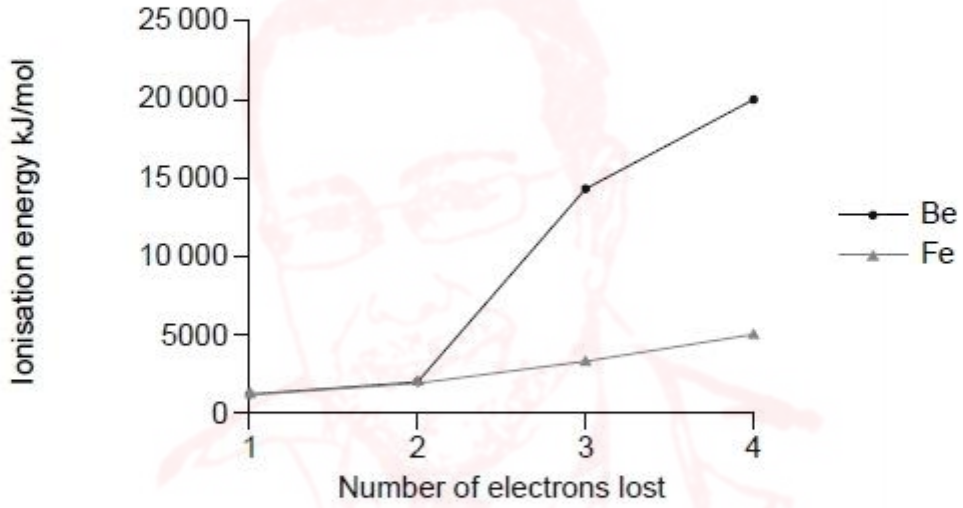
(ii) The first four ionization energies of beryllium and iron are shown.



One common property of transition elements is that they have variable oxidation states. Discuss, referring to the graph, why iron, but not beryllium, displays this characteristic. [3]

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(g) Explain, in terms of nuclear charge, electron subshells and the shielding provided by filled electron shells, why the first ionization energy increases from Li to Be, but decreases from Be to B. [4]

Topic **Chem 3 Q# 25/** IB Chem/2023/s/TZ1/Paper 2/Higher Level/Q9. www.SmashingScience.org :o)

9. (a) Explain why a colorimeter set at a wavelength of 500 nm is not suitable to investigate reactions of Zn^{2+} compounds. Use section 3 of the data booklet. [2]

Topic **Chem 3 Q# 26/** IB Chem/2023/s/TZ1/Paper 2/Higher Level/Q2. www.SmashingScience.org :o)

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

(b) Explain the decrease in first ionization energy from Li to Cs, group 1. [2]

(e) $Mg(OH)^+$ is a complex ion, but Mg is not regarded as a transition metal. Contrast Mg with manganese, Mn, in terms of one characteristic chemical property of transition metals, other than complex ion formation. [2]

Property: .....

Comparison: .....

.....

.....

.....

(ii) Identify a metal, in the same period as magnesium, that does **not** form a basic oxide. [1]

.....

(iii) Copper is a transition metal that forms different coloured complexes. A complex $[Cu(H_2O)_6]^{2+}(aq)$ changes colour when excess $Cl^-(aq)$ is added.

Explain the cause of this colour change, using sections 3 and 15 from the data booklet. [3]

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Topic **Chem 3 Q# 30/** 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.

(a) Explain the general increase in trend in the first ionization energies of the period 3 elements, Na to Ar. [2]

Topic **Chem 3 Q# 31/** IB Chem/2021/s/TZ1/Paper 2/Higher Level/Q3. www.SmashingScience.org :o)

(f) Outline why, unlike typical transition metals, zinc compounds are not coloured. [1]

(g) Transition metals like iron can form complex ions. Discuss the bonding between transition metals and their ligands in terms of acid-base theory. [2]

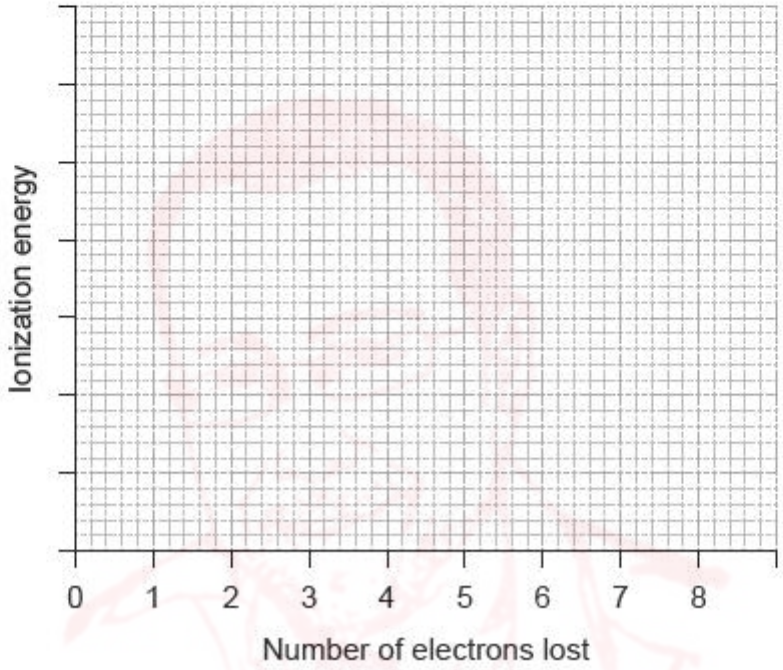
Topic **Chem 3 Q# 32/** IB Chem/2021/s/TZ1/Paper 2/Higher Level/Q1. www.SmashingScience.org :o)

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

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

(b) Justify why sulfur is classified as a non-metal by giving **two** of its chemical properties. [2]

(c) Sketch the first eight successive ionisation energies of sulfur. [2]



Topic **Chem 3 Q# 33/** IB Chem/2020/w/TZ0/Paper 2/Higher Level/Q6. www.SmashingScience.org :o)

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

(b) Explain why a copper(II) solution is blue, using section 17 of the data booklet. [3]

5	e	i	has a partially filled d sub-shell «in a common oxidation state» ✓		1
5	e	ii	IE values of Fe gradually increase ***AND*** IE values of Be show a sudden rise ✓ first and second ionization energies close together therefore do not form a +1 oxidation state / singly charged ion ✓ further IEs of Fe are close to second IE, so the oxidation state/number of electrons Fe loses can vary «according to the oxidizing agents present» ✓	*Accept Be always loses 2 electrons / forms Be^{2+} / only has +2 oxidation state for M2.*	3
5	g		nuclear charge / number of protons increases «for both» ✓ Li and Be «outer electrons have» same subshell/shielding ✓ electron in B lost from p-subshell whereas that in Be lost from s-subshell ✓ «outer electron in» B/p-subshell experiences greater shielding / has higher energy ✓	*Do not accept explanations invoking distance of electrons from nucleus.*	4

Q# 25/ Chem 3 IB Chem/2023/s/TZ1/Paper 2/Higher Level/Q9. www.SmashingScience.org :o)

9.	(a)		Zn^{2+} does not form coloured compounds/ has a complete d subshell/orbital ✓ 500 nm/«the setting on the colorimeter» in visible region ***AND*** no absorbance will be seen ✓		2

Q# 26/ Chem 3 IB Chem/2023/s/TZ1/Paper 2/Higher Level/Q2. www.SmashingScience.org :o)

2.	(b)		valence electron further from nucleus/«atomic» radius larger «down the group» ✓ «electron» more shielded/ less attractive force/easier to remove ✓		2

Q# 27/ Chem 3 IB Chem/2022/s/TZ1/Paper 2/Higher Level/Q4. www.SmashingScience.org :o)

4.	e		*ALTERNATIVE 1* *Property:* variable oxidation state ✓ *Comparison:* Mn compounds can exist in different valencies/oxidation states ***AND*** Mg has a valency/oxidation state of +2 in all its compounds ✓ *ALTERNATIVE 2* *Property:* coloured ions/compounds/complexes ✓ *Comparison:* Mn ions/compounds/complexes coloured ***AND*** Mg ions/compounds white/«as solids»/colourless «in aqueous solution» ✓ *ALTERNATIVE 3* *Property:* catalytic activity ✓ *Comparison:* «many» Mn compounds act as catalysts ***AND*** Mg compounds do not «generally» catalyse reactions ✓	*Accept valency.* *Accept for second statement "Mg «always» has the same oxidation state".* *Accept Mn forms coloured ions/compounds/complexes and Mg does not.* *For any property accept a correct specific example, for example manganate(VII) is purple.* *Do not accept differences in atomic structure, such as partially filled d sub-levels, but award ECF for a correct discussion.*	2

Q# 28/ Chem 3 IB Chem/2022/s/TZ1/Paper 2/Higher Level/Q1. www.SmashingScience.org :o)

1.	a	ii	aluminium/Al ✓		1

Q# 29/ Chem 3 IB Chem/2021/w/TZ0/Paper 2/Higher Level/Q9. www.SmashingScience.org :o)

9.	b	iii	chloride is lower in the spectrochemical series ✓ «ligand cause» decreased/lesser splitting «in d-orbitals compared to H_2O»✓ frequency/energy of light absorbed is decreased ***OR*** wavelength of light absorbed is increased ✓	*Accept ·chloride a weaker ligand than water/produces a smaller energy difference than water for **M1.* *Award **[2 max]** for mentioning splitting of orbitals is changed **AND** frequency/ wavelength/energy of light absorbed are different/changed without mentioning correct decrease or increase.*	3

Q# 30/ Chem 3 IB Chem/2021/w/TZ0/Paper 2/Higher Level/Q2. www.SmashingScience.org :o)

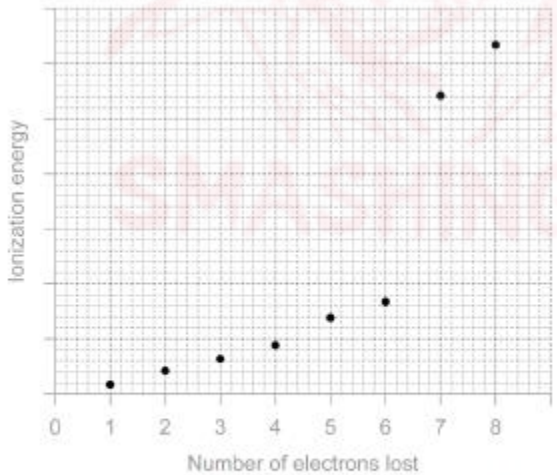
2.	a		increasing number of protons ***OR*** increasing nuclear charge ✓ «atomic» radius/size decreases ***OR*** same number of shells/electrons occupy same shell ***OR*** similar shielding «by inner electrons» ✓		2

Q# 31/ Chem 3 IB Chem/2021/s/TZ1/Paper 2/Higher Level/Q3. www.SmashingScience.org :o)

3.	f		« Zn^{2+}» has a full d-shell *OR* does not form « ions with» an incomplete d-shell	*Do not accept "Zn is not a transition metal".* *Do not accept zinc atoms for zinc ions.*	1

3.	g		ligands donate pairs of electrons to metal ions *OR* forms coordinate covalent/dative bond✓ ligands are Lewis bases *AND* metal «ions» are Lewis acids ✓		2

Q# 32/ Chem 3 IB Chem/2021/s/TZ1/Paper 2/Higher Level/Q1. www.SmashingScience.org :o)

1.	b		*Any two of:* forms acidic oxides «rather than basic oxides» ✓ forms covalent/bonds compounds «with other non-metals» ✓ forms anions «rather than cations» ✓ behaves as an oxidizing agent «rather than a reducing agent» ✓	*Award [1 max] for 2 correct non-chemical properties such as non-conductor, high ionisation energy, high electronegativity, low electron affinity if no marks for chemical properties are awarded.*	2
1.	c		 two regions of small increases ***AND*** a large increase between them✓ large increase from 6th to 7th ✓	*Accept line/curve showing these trends.*	2

6.	b		orange light is absorbed «and the complementary colour is observed» ✓ *Any TWO from*: partially filled d-orbitals ✓ «ligands/water cause» d-orbitals «to» split ✓ light is absorbed as electrons move to a higher energy orbital «in d–d transitions» *OR* light is absorbed as electrons are promoted ✓ energy gap corresponds to «orange» light in the visible region of the spectrum ✓		3