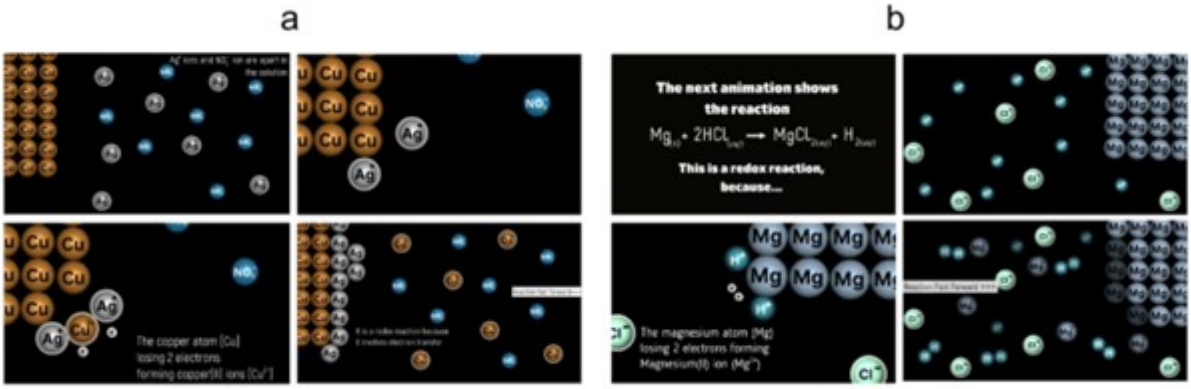
Supplementary Information

Animations are available here

Part A: https://youtu.be/Hg_RwEbSdMQ?si=_LjXBCp7xkt_QobW
Part B: https://youtu.be/G2l8NAJRVLA?si=wbZexWXb7yPSYQYD

Details of Animation Activities (Viewing vs Comparing)

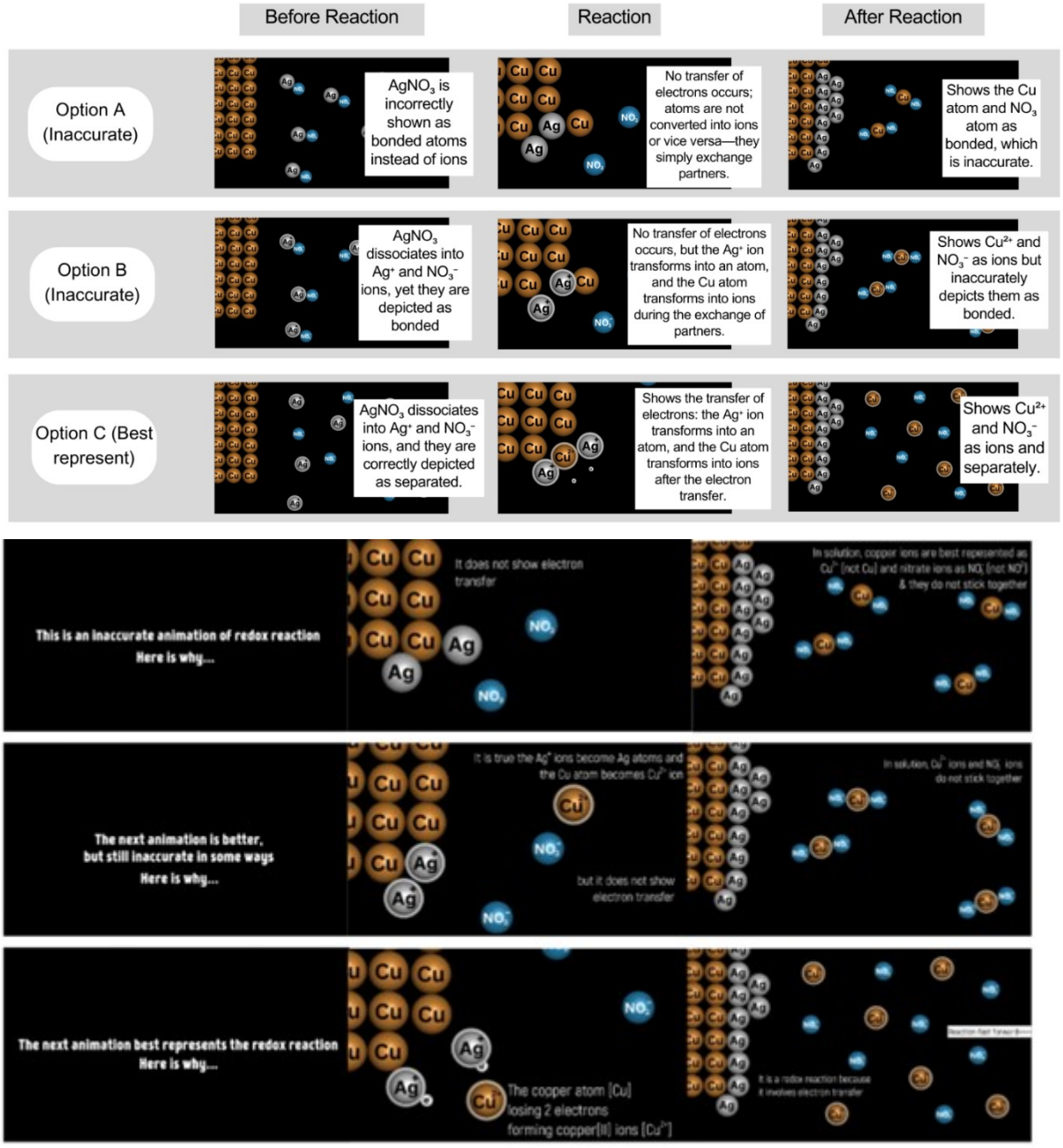
In the **viewing group**, students first watched a video of a laboratory reaction—either copper metal reacting with silver nitrate solution (Part A) or magnesium reacting with hydrochloric acid (Part B). After each video, students viewed an annotated animation that began with the balanced chemical equation, followed by a submicroscopic representation. These animations illustrated key processes, such as dissociation of ions in water, the movement of electrons from metals to ions, and the resulting formation of product species (e.g., Cu^{2+} ions, Ag atoms, H_2 gas). The animations aimed to reinforce accurate mental models by showing the full sequence of redox events, including charge changes and interactions between solute particles.



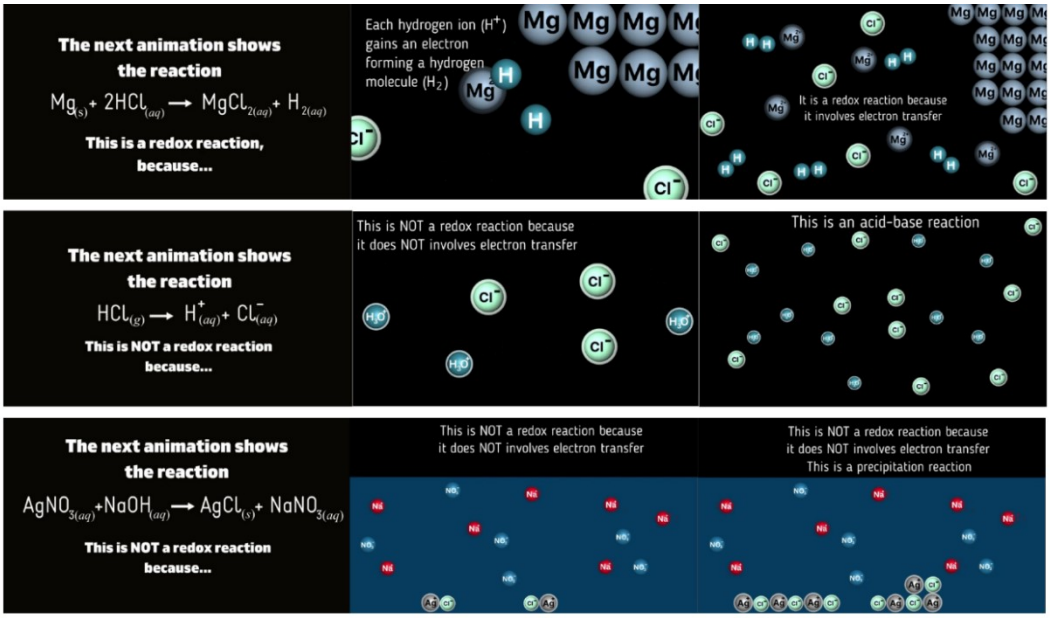
Part A. Copper and Silver Nitrate Part B. Magnesium and Hydrochloric Acid

In the **comparing group**, students also watched the same experimental videos but were shown three different animations representing the same redox reaction. Only one animation accurately depicted the process; the other two were deliberately flawed based on common misconceptions (e.g., ions shown as bonded in pairs in aqueous solution, no charge changes after electron transfer, or incorrect interpretation of the solution's color). Students were asked to select the animation they believed best represented the reaction and explain their reasoning. If an incorrect animation was selected, they were informed and allowed to choose again. Afterward, students were shown the correct narrated animation used in the viewing group. In Part B, the comparison task included one redox reaction animation and two distractor animations representing non-redox processes (e.g., acid-base dissociation and precipitation), requiring students to identify the reaction that actually involved electron transfer.

Part A (Copper and Silver Nitrate Reaction)



Narrated Feedback Part A. Copper and Silver Nitrate

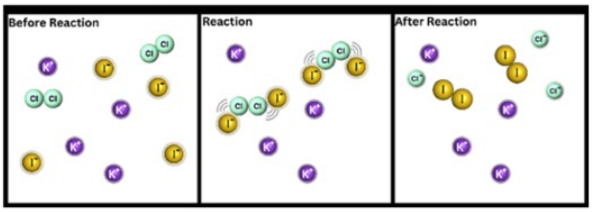


Narrated Feedbck Part B. Redox and Non-Redox Reactions

Reaction 1

Chlorine solution and potassium iodide solution
Changes: colorless solutions form reddish-brown color

Option A (Best represent)

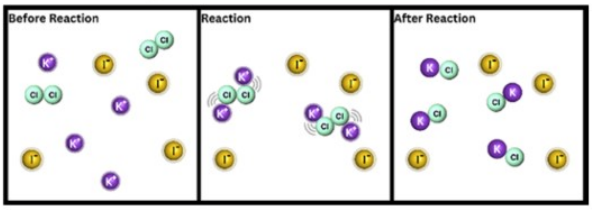


KI dissociates into K^+ and I^-. Macroscopically appears as a colorless solution.

Appropriate transfer of electrons: I^- ions donate an electron to chlorine (Cl) atoms.

Cl atoms gain an electron to become Cl^- ions, while (I^-) lose an electron, becoming iodine (I) atoms. s combine to form I_2, responsible for the reddish-brown color.

Option B (Inaccurate)

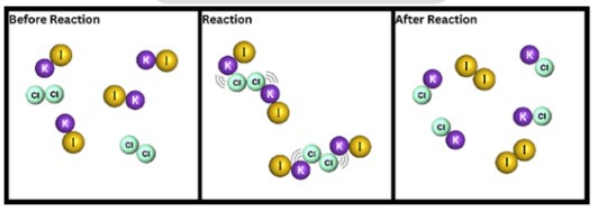


KI dissociates into K^+ and I^-. Macroscopically appears as a colorless solution.

K^+ is incorrectly shown bonding with Cl. No electron transfer occurs.

KCl is shown as bonded atoms, which is incorrect. I_2 formation and reddish-brown color are missing.

Option C (Inaccurate)



KI is incorrectly shown as bonded atoms, not ions

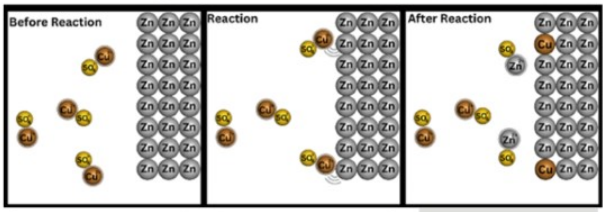
Cl and I are shown as bonding partners, which does not represent the redox process.

KCl is shown as bonded atoms, which is inaccurate. I_2 is shown accurately and is responsible for the reddish-brown color.

Reaction 2

Zinc metal and copper(II) sulfate
Changes: the reddish-brown copper metal appears and the blue solution fades

Option A (Inaccurate)

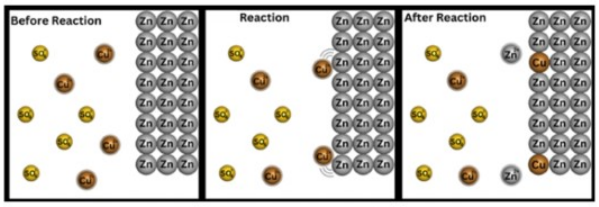


Cu^{2+} ions and SO_4^{2-} ions are incorrectly shown as bonded together.

The transfer of electrons from zinc (Zn) to Cu^{2+} ions is correctly depicted.

Zn^{2+} ions and SO_4^{2-} ions are incorrectly shown as bonded together, which does not represent the products of the reaction.

Option B (Best Represent)

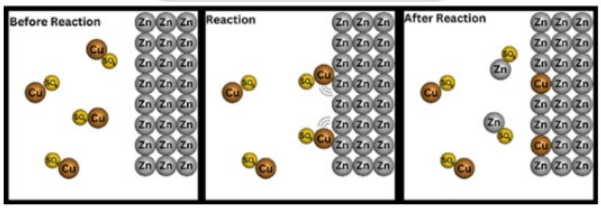


Cu^{2+} ions and SO_4^{2-} ions are correctly shown as separate ions in solution.
- Cu^{2+} is responsible for the blue color of the solution.

The electron transfer is accurately depicted: zinc (Zn) atoms lose electrons to Cu^{2+}, reducing Cu^{2+} to copper (Cu) atoms.

Zinc atoms lose two electrons to form Zn^{2+}. Cu^{2+} gain electrons to become Cu, leading to the appearance of copper metal and the fading of the blue color.

Option C (Inaccurate)



Cu and SO_4 are incorrectly shown as bonded atoms instead of dissociated ions.

The diagram does not depict the electron transfer, instead showing a simple position exchange between Zn and Cu.

The final state inaccurately shows Zn and SO4 atoms bonded together, which does not represent the correct reaction products.

Student	Answer	Questions
Reaction 1		
A1 (A)	because it's showing how the chlorine ions are not attached due to the redox reaction **Interview:** It was in the animations and you can see that the ions. Not attached. To so obviously that Iodide is what creates the colour right and like you could see that the ions were in the solution. Weren't attached like they are in the other. You're not. The other ones have after reaction and their ions aren't really floating correctly. So you can see the chlorine, the chlorine, chlorine ions. They had to. Well, they were not ions. There are molecules and then they gained an electron and they became the ions and got separated in the solution and the opposite for the iodine. So they the. I lost its electrons and formed to the molecule.	
A2 (A)	Before the reaction, there's chlorine molecules, which would be in the chlorine solution, and potassium and iodine ions, which would be present when potassium iodide is dissolved. During the reaction, electrons are transferred from the iodine ions to the chlorine atoms, so electron transfer/a redox reaction occurs.	
A3 (A)	Potassium iodide portrays the ions as separate, as shown here.	
A4 (A)	Because I thought KI meant I was in the I- state, and then the chlorine would be originally Cl2(aq), and then gain the electrons	
A5 (C)	Because the questions said potassium iodide and KI is potassium iodide **Interview:** Cause I just thought that these two [option A and B] are wrong 'cause. Like, K+, potassium in like Iodine like separated. I thought they had to be like in together.	**Which diagram best represents reaction 1?**
A6 (C)	Cl oxidation changed from 0 to -1 and I oxidation changed from -1 to 0. Cl also bonds to K+. **Interview:** option CI think the K bonded like the K bubble touching the I bubble shows that that's potassium iodide. And chlorine being CL 2. So two of those bubbles together and then in the middle part during the reaction with the chlorine touching the potassium, the K potassium, I think that's showing the electrons being exchanged. And then in the after reaction with the potassium bonded to the chloride and then I just being bonded to itself. I thought that was best represented by that one.	
A7 (C)	it shows that potassium iodide (KI) is a compound as K and I are stuck together. Cl2 is a diatomic molecule which are clearly shown as well as the Cl2 are stuck together as well for the before reaction. During the reaction it shows that Cl2 is reacting with the K part of the Kl and the after reaction with I2 being separated giving it the brown color as KCl forms, which shows what happened while watching the reaction video	
A8 (B)	K and I ions are aqueous so they would be separated before reaction?	
B1 (A)	It shows the iodine ions get the electrons to become iodine and the chlorine becomes chlorine ions.	
B2 (C)	It shows K+ and I- as separate ions and has iodine ions separate at the end, which I remember were responsible for the reddish-brown colour. **Interview:** My reason for not choosing A would be that. Potassium and chlorine ions would be attracted to each other because they have opposite charges and. So yeah, A would not be correct with the after reaction diagram. I think that maybe. Maybe B might not be correct because it in the before reaction diagram it has Potassium and iodine separate, but I think that they would be together in potassium, iodine or iodine. The solution? And I think at the end, iodine would Be Neutral and potassium and chlorine would have would be ions like together. And I think I think C would be more correct because. It in the after reaction it demonstrates that. Potassium and chlorine are together and in the before reaction, potassium and iodine together and then iodine. Is on its. It is separate	

	and the after reaction. And I think that iodine would be. Oxidised to from II minus to I2 and so it shows 2 ID molecules together and I think that looks more correct than b	
B3 (B)	Because K is a positive ion and Cl would be a negative ion	
B4 (B)	Ions with right matches	
B5 (C)	I am assuming once mixed, they joined to create a compound **Interview**: I don't. I think it might have been because the potassium and chloride were reacting, but I wasn't quite sure. (Change to choose C)	
B6 (C)	Potassium and Iodide are together in solution	
B7 (C)	Because it shows potassium iodide as a compound **Intervew**: potassium iodide was what do you want to call it? A compound and A and B did not show that. It shows all the ions individually rather than as a compound.	
A1 (B)	i don’t think it’s a correct representation of a redox reaction	
A2 (B)	I feel like that the reaction shows a covalent bond forming between potassium and chlorine atoms, as after the reaction they are bonded together. This means no electron transfer and no redox reaction occurred.	
A3 (B)	The Potassium and Chloride atoms are attached, which should not be the case, as there should be K+ and Cl- ions. Also, the iodide molecule is not shown.	
A4 (B)	Because why would the neutral Cl and positive K be more attracted to each other than I- and K+	
A5 (A)	Because potassium and iodide are separated	
A6 (A)	The chlorine ions are not bonded to the K+.	
A7 (A)	It implies that the potassium and iodine are not a compound but ions in the solution. It can be misleading and some might think it's separate ions and not KI as a compound. It also shows that Cl2 reacts with the iodine ions which is inaccurate as it actually reacts with the K instead to form KCl and I2 gas.	Reason why not choose
A8 (A)	Cl reacting with I and then not forming anything seems weird	
B1 (B)	The wrong charge was given.	
B2 (A)	I don't think I- and Cl would react together more readily than K+ and Cl because I and Cl are both halogens and K is a metal (larger difference in electronegativity to a halogen).	
B3 (A)	Both are negative ions, so it doesn't work	
B4 (A)	Cl is a anion	
B5 (A)	Because at the end iodine and K and Cl are all still seperate	
B6 (A)	Potassium and Iodide are not together	
B7 (A)	It shows all of the ions individually	
A1 (C)	i don’t think it is accurately showing what happens during a redox reaction	
A2 (C)	Potassium iodide separates into ions when dissolved, which isn't shown before the reaction. Also iodine atoms after the reaction are still neutral somehow.	Reason why not choose
A3 (C)	The Potassium and Chloride atoms are attached, which should not be the case, as there should be K+ and Cl- ions. Only the Iodide molecule should be shown as attached	
A4 (C)	Because nothing changes	

A5 (B)	Also, for this one, potassium and iodide are separated.	
A6 (B)	Iodine changes from -1 to 0 therefore after reaction there should not be Iodine ions	
A7 (B)	again, the iodine and potassium exists as separate ions and not as a compound together in the before part of the reaction. as for the after reaction, it shows that iodine is still an anion and not a diatomic molecule (I2) which would be inaccurate in terms of how the reaction works as it forms KCl and I2 as a product.	
A8 (C)	Everything is in molecules so doesn't seem to be in solution	
B1 (C)	In the solution, KI is ionization.	
B2 (C)	K and I are not joined together in potassium iodide solution.	
B3 (C)	No ions here, showing no electron transfer, so its not a good representation	
B4 (C)	C They are all neutral	
B5 (C)	Actually, I now think it may be this one, as I am now thinking it was potassium iodide, meaning they would be compound in the beginning.	
B6 (B)	Potassium and Iodide are not together	
B7 (B)	It shows all the ions on their own at the beginning and iodine on it's own at the end instead of i2	
A1	The colour change forms because of the formation of Iodine molecules	
A2	The iodine molecules formed during the reaction have a reddish brown colour and make the solution appear reddish brown after the reaction. Before the reaction there are no iodine molecules.	
A3	The potassium chloride molecule absorbs different wavelengths of light than iodide. Also, the exchange of electrons likely emitted photons with a certain wavelength.	
A4	The Potassium iodide (KI) is initially colourless, but when the electron transfer occurs from I to Cl, I(s) forms, which is reddish-brown	
A5	The color change is due to chlorine oxidation of iodide to iodine. Dissolved iodine makes the reddish brown color.	explain the color change (colorless to reddish brown)
A6	The change in color is due to potassium chloride being formed	
A7	KI is colorless but when Cl2 is added and KCl and I2 forms as a result, I2 gives off that reddish brown color to the solution. Option C shows this as it shows KI molecules and Cl2 molecules interacting with each other with Cl interacting with K which results in KCl and I2 together.	
A8	I have no idea	
B1	Yes, the I2 becomes I- make the solution change colourless to red-brown.	
B2	I- ions make the reddish-brown colour	
B3	im not sure, the colours are correct in the diagram.	
B4	Yes s different compounds have formed	
B5	I am unsure why the color actually changes, **Interview**: All of them responsible And Iodine as spectator ion	
B6	Elements switch bondin	
B7	I'm not sure what you mean?	
A1	Chlorine got reduced as it gained an electron to form Cl- and Iodide was oxidised as it lost electrons to form I2	which

A2	Iodine ions were oxidised and chlorine atoms were reduced.	chemical species underwent oxidation reduction?
A3	Since the iodine lost an electron, it underwent oxidation. Since the chlorine atoms gained electrons, they underwent reduction	
A4	The Iodine underwent oxidation, and the chlorine underwent reduction (K+ spectator ion).	
A5	Iodide went under oxidation and chlorine went under reduction	
A6	Iodine underwent oxidation (lost electrons to become more positive -1 to 0). And chlorine underwent reduction to become more negative 0 to -1)	
A7	iodine got oxidised, chlorine got reduced	
A8	I'm not sure	
B1	The iodine underwent oxidation, chlorine underwent reduction	
B2	K+ gained electrons so it was reduced and Cl donated/lost electrons so was oxidised	
B3	Cl,- gained an electron so it underwent reduction, while K+ lost an electron once it bonded with Cl-, so it underwent oxidation	
B4	Iodine lost electron so oxidation And chlorine gained electron so reduction	
B5	Iodine was the reductant I think, and oxidant maybe Cl	
B6	Chlorine is oxidised and Iodide is reduced	
B7	I2	

Student	Answer	Questions
Reaction 2		
A1 (B)	because it shows the copper ions joining with the zinc to become solid and the zinc and so4 ions floating in the solution. **Interview:** Joins the zinc lattice there, so it must be gaining the electrons to make that neutral, and then you can see the zinc ions losing its electrons and lose leaving the formation. Well, so the solution is an aqueous solution and it's got copper sulphate like molecules in A and. B, which is an inaccurate deposition of the solution.	
A2 (B)	Copper (II) sulfate separated into ions in solution and electron transfer occurred between copper ions and zinc atoms.	
A3 (B)	The ions should not be attached, even if they do form bonds.	
A4 (A)	Because the Cu is being reduced and Zn oxidised, in line with the observations	
A5 (A)	Because Zinc loses electrons and forms Zn2+ ions (dissolved in solution). Copper(II) ions (Cu2+) gain electrons and get reduced to form solid copper (Cu) metal, which deposits on the zinc surface.	
A6 (A)	Shows that copper is bonded to sulfate then electrons are transferred between zinc and copper, then zinc bonds to free sulfates **Interview**: I think I chose that one because it shows in the before reaction. It shows the two bubbles for the copper and sulphate as bonded together and then with the like exchange of electrons. Being shown in the during the reaction shows the. Either the copper or the exchange of electrons between copper and zinc, and then the after reaction I thought showed the best of how zinc was then. Bonding with sulphate.	**Which diagram best represents reaction 1?**
A7 (C)	it shows CuSO4 as a whole molecule in itself and shows specifically how the switch between Cu and Zn happens	
A8 (-)	-	
B1 (B)	It shows the electrons change. Before reaction the CuSO4 in the solution is ionization	
B2 (B)	It shows Cu2+ and SO42- as separate ions in solution throughout the reaction **Interview**: before reaction and during the reaction it shows that copper, the copper ions and the sulfate ions Are separate, which is what I believe happens when it's in an aqueous solution and not a solid.	
B3 (B)	The Cu2+ and SO4^2- aren't connected, which is what their meant to be like.	
B4 (-)	-	
B5 (C)	Because they started off as a compound, then it seems like it shows Zn donating e to Cu **Interview**: yeah, I think it was because I did say it started off as a compound. And that so that. Transferring the electrons from the zinc to the copper. So then the zinc and the sulphate reacted.	
B6 (B)	Copper replaces Zinc (Copper and Sulfite are not directly attached)	
B7 (C)	I'm not actually sure. Atomic radii? **Interview**: Tossing between A and C bcs I assume it's a compound, right? You assume. It's. Something that's together.	
A1 (A)	because it’s inaccurate	
A2 (A)	Copper (II) sulfate did not separate into ions in solution, and I'm not sure if it's correct for the ion charges to show on copper sulfate when it's in a molecule.	Reason why not choose
A3 (A)	Same reason as earlier.	
A4 (B)	Because Zn loses 2 electrons but they aren't transferred to another atom	
A5 (B)	This is wrong because SO42- and Cu2+ are separated	
A6 (B)	This to me shows that the copper and sulfate are not bonded together.	

A7 (A)	Option A is similar to C so i think it's also a decent representation of what is happening during the reaction	
A8 (-)	-	
B1 (A)	I think the before reaction image is not right.	
B2 (A)	It does not show Cu2+ and SO42- as separate ions in solution throughout the reaction and indicates that Zn2+ ions join to SO42- ions after the reaction.	
B3 (A)	Cu2+ and SO4^2- are connected at the start, which is incorrect	
B4 ()	-	
B5 (A)	I am not sure, this one actually seems the same option C, I cannot tell the difference	
B6 (A)	Copper and sulfite attaches	
B7 (A)	It could be correct, I'm not sure	
A1 (C)	because it is also inaccurate to what is happening	Reason why not choose
A2 (C)	Copper (II) sulfate did not separate into ions in solution.	
A3 (C)	Same reason as earlier.	
A4 (C)	Because no electron transfer takes place, so it is not clear why Zn and Cu swap places	
A5 (C)	Honestly I can't tell the difference between option A and C.	
A6 (C)	Looks pretty similar to option A, I cant tell the difference	
A7 (B)	it doesn't accurately show which compounds are formed after the reaction nor what compounds are present in the solution, only the ions. It may be a bit confusing.	
A8 (-)	-	
B1 (C)	I think the before reaction image is not right.	
B2 (C)	It does not show any of the elements as the ions that they are in solution.	
B3 (C)	SO4^2- are connected, its incorrect	
B4 (-)	-	
B5 (B)	Because in first 2 steps copper and solfataras are seperate from each other	
B6 (C)	Copper and sulfite attached	
B7 (B)	It shows cu and so4 individually	
A1	because copper becomes apart of the lattice as seen in the picture so it leaves the solution (so the blue leaves) and forms a solid with the zinc ions **Interview**: that's because the blue was from the copper ions. There were. Floating in the, you know, aqueous in the solution. And that reacted with the zinc, the solid zinc. And the the precipitate that was formed from that was the. So the Zincs was losing. The zinc was, yeah, losing its electrons and the copper gained electrons going into the. And becoming the solid with the.	explain the color change (colorless to reddish brown)
A2	The ions in solution cause the blue colour of the solution. When the copper ions gain electrons from zinc, the copper metal appears and the copper ion is no longer dissolved in the solution and so the blue colour fades	
A3	Copper atoms, which give off different wavelengths to silver, replace the silver atoms, while copper sulfate is replaced with zinc sulfate, also gives off a different wavelength.	
A4	Because solid copper is forming while solid zinc is dissolving	
A5	The reddish-brown copper metal appears because Cu2+ ions in the blue CuSO4 solution are reduced to solid Cu on the zinc surface,	

	while the blue solution fades as Cu2+ ions are removed from the solution.	
A6	Blue colour was from the aqueous copper sulfate and that fades to reddish brown metal is solid copper forming. **Interview**: So as the copper like the redox reaction was occurring and the copper was turning into a solid, it was being removed from the solution. So that's why the blue color was fading.	
A7	the blue solution is because of the Cu2+ in CuSO4 but as it gets reduced to Cu and ZnSO4 forms, a precipitate forms (the reddish brown copper metal) it is shown in option C as we could see that in the after reaction, there's less CuSO4 as the Cu becomes part of the big block of Zn metal as it forms solid Cu metal and ZnSO4 forms as well	
A8	-	
B1	The Cu2+ becomes Cu solid	
B2	Blue solution fades because less Cu2+ (blue colour) are present as they become solid Cu. Reddish-brown copper metal appears because Cu2+ ions were reduced to Cu metal. **Interview**: copper, copper, 2+ions are blue or like they show up as blue and so as they are being. Reduced to copper metal on the. Like zinc metal there are less copper solutions in the solution, making it less blue and making the colour fade.	
B3	The two colours mix and cancel each other out, so colour fades	
B4	-	
B5	No idea, maybe the color reduces as the elements mix Interview: Interviewer: “who responsible for blue color at the first?” Students : “Copper sulfate, both as togehthe”	
B6	Zinc and copper switch places	
B7	I don't actually fully understand the redox idea **Interview:** “The color Blur is from Copper and the black cristal I'm assuming that's the zinc.”	
A1	copper went through reduction as it gained electrons and zinc went through oxidation	which chemical species underwent oxidation reduction?
A2	Copper ions were reduced and zinc atoms were oxidised.	
A3	Copper, gaining electrons, undergoes reduction, and silver, losing electrons, undergoes oxidation	
A4	Cu(2+) underwent reduction and Zn(s) underwent reduction	
A5	copper went through reduction as it gained electrons and zinc went through oxidation	
A6	Zinc underwent oxidation (0 to +2) and copper underwent reduction (+2 to 0)	
A7	Cu is reduced, Zn is oxidised	
A8	-	
B1	Zinc underwent oxidation and Cupper underwent reduction	
B2	Cu2+ ions underwent reduction (gain of electrons) and Zn metal underwent oxidation (loss of electrons).	
B3	Cu2+ gave 2 electrons to Zn, so it underwent oxidation,	
B4	-	
B5	Zn reductant, copper oxidant	
B6	Zinc was oxidised and copper was reduced.	
B7	Zinc	