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Integrating formative assessment into the design of a science unit.

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Abstract

Formative assessment, or assessment for learning, is a promising approach in which assessment is no longer a tool to rank student performance but a process that provides feedback about the teaching and learning processes as they are happening.

This master thesis is structured as follows:

- Background research. The problem derived of using assessment only as an evaluation tool and the benefits of the use of formative assessment to promote learning are discussed.

- Implementation of formative assessment in the classroom. The main features of formative assessment – sharing learning goals, effective questioning, feedback, self-assessment and peer-assessment– have been reviewed and have been used as foundation for the preparation of an educational unit.

- Context. Description of the school for which the didactic unit created in this work has been designed (the International American School of Rotterdam).

- Unit. A thorough description of a Science Unit, ready for implementation, in which formative assessment has been carefully included. The Unit includes 14 activities with all the materials needed for its application in the classroom. In each of the activities, formative assessment has been included.

The main objective of incorporating formative assessment in the Unit is that both teacher and students get immediate feedback about the learning process. With this information, teachers can tailor their instruction to meet students' needs, and students are aware of where they are on their learning and how they progress with reference to the learning goals.

The application of the Unit is expected to result on a significant improvement on students' learning, increased motivation towards the learning process itself, and self-reflection. All this aspects will make students take control of their own learning.

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1. Introduction

This master thesis (TFM) discusses the implementation of formative assessment in the classroom. Its objective is to show how formative assessment can be effectively used in a Science unit, therefore being included in modality 3: “Planning and/or curriculum”. A detailed plan has been prepared for its direct implementation in a Grade 8 Science classroom, based on the key elements of formative assessment that are described in the background section.

Personal Engagement

In my personal experience as a teacher, I have realized that some of the assessment techniques that are usually implemented are not part of the learning process; they are just merely achievement measuring techniques that do not benefit students or teachers. I quickly became interested in assessment, and wondered whether assessment could be part of the learning dynamic; I wanted students to be able to succeed, and I also wanted to have tools that would allow me to modify my teaching techniques for a better success. In the past, I have said to myself many times “I need to change this lesson” or “I should have done this differently”, but this feedback arrived usually at the end of the lesson, when I was already focusing on preparing the next topic.

I have also worked with wonderful teachers who care about their students, and do as much as they can to help them learn. I have seen them use formative assessment in their lessons, and it was always with positive results: students knew what to do to improve, and were eager to try; and teachers were aware of their students’ achievement, and knew what needed to be reviewed and what was mastered already.

This project is a compilation of those experiences, and the research that is out there. This is the structure that I have followed:

- Background research – types of assessment and the basis of formative assessment
- Implementation in the lessons – formative assessment strategies
- Context – description of the school for which this work was created
- Unit – a thorough description of a Science unit, in which formative assessment has been carefully included

Prologue

> *'It is the end of the term and I feel quite tired after so many exams. Luckily, holidays are coming soon and my mind is completely focused on what I am going to do during my vacation. At that point, the teacher enters the room. She says nothing, but her face is frightening and we all shut up. She takes the last test results out of her bag and starts to hand them out around the classroom. I get my score and it is not what I expected. I had studied so much but I barely passed the test. The teacher is upset with the results and starts a speech about how much we need to improve, the effort we need to put forth and something else, but I am not really listening to her. I start to ask my friends about their scores. It is not so bad; we all have low grades, apart from the few that always score high and are smiling in the first row. It could have been worse; at least, I passed. I start to add up the marks for each section; maybe she forgot to count something or made a mistake adding them together. I was not that lucky. Anyway, it is just a test. I can always try to score higher in the next term to raise my final grade.'*
>
> *Personal experience*

2. Background

Every time that I try to recall assessment, something similar to the prologue comes to my mind. For the last 40 years, the educational community has been warning about the negative effects that this kind of assessment can have on learning. Despite that awareness, this is what I experienced during my time as a student and not too far from what you can see in most classrooms nowadays. Let's get a closer look to a few sentences of the prologue that exemplify some of the problems of traditional assessment.

- **"It is the end of the term"** – traditional assessment is usually done at the end of a time period or when a unit is finished. At this moment, assessment results are probably late for the teacher, who cannot take actions to improve his/her teaching; and also for the students, who have moved forward to next unit without having acquired the desired learning.
- **"I get my mark and it is not what I expected. I had studied so much but I barely passed".** – There is a general believe among teachers that the assessment process is a secret that will only be revealed to the students on the test day. Most students don't really know what they are going to be tested on, nor what the learning goals are for the unit, and they end up failing despite putting forth a lot of effort.

- **“The teacher is upset”** – Most teachers get upset with students’ performance when it does not meet their expectations, and they don’t know what to do to help students improve their understanding. This happens mainly because the assessment is too late to modify the teaching-learning process; teachers feel frustrated and their only escape route is to praise students who scored high and to blame those who did not.
- **“I start to ask to my friends about their marks”** – Assessment designed for ranking promotes competitiveness among the students, who are trying to score higher than their classmates. This also prevents them from self-reflecting about their learning experience and how to improve it.
- **“The few that always score high and are smiling in the first row”** – There are students that get high scores in a regular basis mainly because the way of instruction fits them well; traditional assessment works for them because it boosts their self-confidence. On the other hand, students that score low might be negatively affected by traditional numeric assessment, which diminish confidence regarding their capabilities to learn.
- **“I can always try to score higher in the next term to raise my final grade”** – Students know that even if they score low on a certain topic that they don’t understand properly, they can still compensate their average grade on the subject by getting a higher score on other topics they find easier.

Can we blame assessment for all this problems?

Assessment might not be the cause of the situations above but instead part of the solution. Research has shown that assessment can be a powerful tool to increase student learning. Robert J. Marzano, in his book Classroom Assessment and Grading that Works[1], summarizes the conclusions from Black and William[2] in a graph, showing the dramatic effect that modifying assessment has on student achievement (Figure 1). If teachers increase their skills on using assessment in the classroom from the 50th to the 99th percentile, student achievement is predicted to increase up to the 78th percentile. It is worth mentioning that when Marzano talks about increasing teacher skills on assessment, he implies a change on the quality of assessment practices (and not in the frequency) in order to improve the learning process.

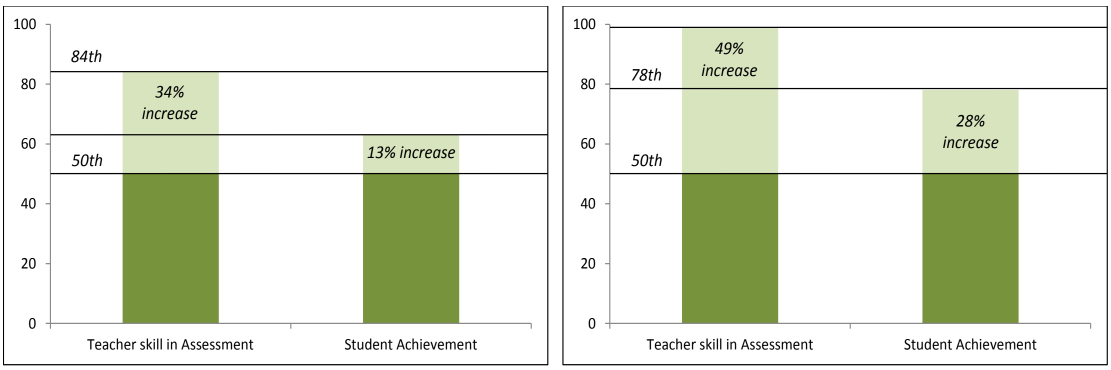

Fig 1. Student achievement predictions. Adapted from Marzano et al. 2006

Why do we need assessment?

The knowledge achieved by a student after instruction cannot be predicted. It would be unwise to think that all the objectives have been reached at the end of an educational activity or that all students reached the same level of understanding; that is why assessment is crucial for an effective instruction. We can define assessment as the systematic collection, analysis and recording of information about student learning. Although with some discrepancies on the definitions between authors[3], assessment can be classified into two main categories:

- Summative Assessment (or assessment of learning): This assessment usually takes place at the end of an educational sequence or academic year and determines what the students know and do not know relative to content standards. It is usually reported in the gradebook as scores.

- Formative Assessment (or assessment for learning): It is part of the instructional process used by teachers and students and it provides feedback on teaching and learning while they are happening. Effective formative assessment collects evidence about the gap between students' understanding and the desired goals and helps modifying the instructional process in order to close that gap.

In the last decades, most educators and researchers have focused their effort on learning more about formative assessment and the benefits that it might have on the learning process; however, the difficulties to measure the effectiveness of formative assessment on improving achievement results in mixed community of educators, with different perspectives, beliefs and opinions. Teachers are still divided into supporters of summative assessment and supporters of formative assessment.

> ***When the cook tastes the soup, that's formative assessment; when the customer tastes the soup, that's summative assessment***
>
> **Robert Stake**[21]

Summative assessment supporters recognize some of the theoretical benefits of formative assessment; however they base their arguments against it on its lack of applicability in the classroom. Implementation of formative assessment requires more effort than just sticking to summative assessment; also, the current configuration of the classroom, with one teacher every thirty students, results in a workload that a few teachers are willing to take. Furthermore, they defend their position arguing that they are only expected to give a grade at the end of the school year, and that this is the only thing that the educational community (students, parents and institutions) cares about.

On the other side of the discussion are formative assessment supporters. For them, the benefits of formative assessment on student learning overcome all the effort needed for its implementation. They constantly know which way of instruction is working or not, and are able to modify it based on the feedback the formative assessment provides them with. At the same time, both teachers and students know which learning goals have been achieved already, and which ones still need more work, making students aware and involved in their own learning process. These educators believe that summative assessment arrives when it is too late to modify instruction and usually in the form of a numerical grade that barely gives any information about student knowledge.

Is summative assessment preventing learning, as some teachers think? If so, should we avoid summative assessment at all and replace it with formative assessment?

Summative assessment is a tool that allows us to determine what the students know and do not know at a particular time point. Therefore it has to be used when wanting to measure students' achievement (a student might move to a different school and his records would be needed, university acceptance, etc.). The problem comes when summative assessment is the only type of assessment used. Introduction of formative assessment in the classroom will allow for modifications to be done before it is time for summative assessment. It also provides the teacher with frequent information about students' achievement; in the case of a successful student having a "bad day", the teacher would have had enough information to realize that the score does not reflect what the student has shown he/she knows.

3. Implementing assessment for learning in the classroom

Implementation of formative assessment in the classroom is not an easy task and it requires the efforts of the whole educational community. The shift depicted on Figure 2 will be required of the educational community.

With the goal of providing a theoretical grounding for formative assessment, Wiliam and Thompson[4] defined three key processes in learning and teaching:

- Establishing **where the learners are in their learning**
- Establishing **where they are going**
- Establishing **what needs to be done to get them there**

With the above in mind as the plan of action, these are some of the strategies that researchers have shown build the basis of formative assessment[5,6]:

- Sharing learning goals and success criteria.
- Questioning and effective classroom discussions.
- Feedback.
- Peer-assessment.
- Self-assessment.

FROM		TO
Focus on teaching	➤	Focus on learning
Emphasis on what was taught	➤	Fixation on what students learned
Coverage of content	➤	Demonstration of proficiency
Learning for some students	➤	Learning for all students
Infrequent summative assessment	➤	Frequent formative assessment
Determine which students fail to learn by the deadline	➤	Identify students who need additional time and support
Assessment used to reward and punish students	➤	Assessment used to inform and motivate students
Focus on average scores	➤	Monitor each student skills
One opportunity to demonstrate learning	➤	Multiple opportunities to demonstrate learning
Learning by listening	➤	Learning by doing

Figure 2. Educational shift adapted from DuFour et al. [7]

3.1. Sharing learning goals and success criteria

The chances of successfully performing a task in any aspect of life without knowing the final goal or how success looks like, are rather low. Let's look at a made up situation to understand this better:

> *Imagine that you end up in a remote place where all people sit on the floor; they have never seen a chair. As you are not used to it, you find sitting on the floor quite uncomfortable and decide to ask a carpenter to make you a few chairs. He has all the materials, tools and enough expertise to build any piece of furniture, but would you expect him to be able to build a chair if he doesn't know what a chair is or what it is for? You would need to explain him what a chair looks like, which key features need to be there or show him a picture of a chair so he can build one.*

This also applies to the learning process; students will achieve the learning goals only if they understand them properly and can monitor their progress towards them[5].

Most of the times learning goals are set by "educational institutions" and expressed in the format of standards that the students need to meet at the end of the instructional period. These standards are not easy to understand. They are too abstract and sometimes even teachers have problems to decode their meaning. Teachers should select those standards that are essential for their students, rephrase them in a way that students can understand and share them with the students. But work does not end with sharing the goals; teachers need to confirm that all students have understood those goals and if not, clarify them, rephrase them or modify them so students not only understand the standard but also why meeting that standard is important for their learning.

3.2. Questioning and effective classroom discussions

From a social constructivism point of view, classroom discussions and interactions with the teacher and the rest of students can help students construct knowledge and develop skills that they would not be able to achieve independently[8]. Questioning is not only an effective tool to assess what students know, but also a mechanism to engage students in discussions and self-reflection that will promote learning.

Teachers ask questions daily, with some asking up to 400 questions a day[9], but most of these questions will never promote learning. ***Why?*** Teachers use questions during their discourse in order to check attention and control the level of understanding of students. They are normally short and direct questions looking for a short, correct answer. They become blurred within the teacher talk, and students do not get any learning from them. In order to be effective, not only the questions but the whole process around them should meet the following criteria:

- Question: it must encourage thinking; most of the questions teachers ask have come to their minds just a few seconds before asking them. That does not necessarily imply that they are ineffective questions, but they could have been much better if planned in advance. A good question has to awake student curiosity, stimulate thinking, relate with what students already know, be open to multiple answers and, at the same time, drive the discussion to the point the teacher wanted.
- Waiting time: good answers need to be properly thought and that requires time. Average waiting time is in the second range[10], mainly due to the discomfort that silence causes to teachers. Longer periods of time allow students to think about the question and to relate it with their previous knowledge; they then end up with longer and more elaborate and creative answers, or even with new questions that will promote discussion.
- Dealing with the answer. Teachers are usually expecting the right answer so they can rapidly move to the next topic; they should instead listen carefully to the answers in order to identify how the students think or to find points that have room for improvement.

3.3. Feedback

We can define feedback as a process in which the output of an action is used to modify the next action.

What is good feedback?

Let's look at my personal experience:

> *Until recently, the word feedback and a fear sensation went always hand in hand for me. I have always been uncomfortable giving feedback to others; I was afraid of saying something I might regret afterwards or hurting their feelings. And the same occurred when I was about to receive feedback: I became tense and took a defensive attitude. Why was this happening? Easy answer: because of ego.*

This is a situation that most people experience at some point in their life. The feedback they might have received was probably not appropriately communicated.

Good feedback though, should cause thinking instead of emotional reactions. It should point out where the student is and how he/she can move forward. This cannot be achieved if only a numerical grade is given as feedback; comments-only feedback has shown to be much more efficient[11].

Good feedback has to be specific, actionable, timely and respectful[12].

- **Specific:** feedback has to point out what has worked well (behaviors to reinforce) and what needs improvement (behaviors to modify). When several areas need improvement it is better to address only one or two main skills at a time; bombarding students with feedback will most probably disengage them.

We should always pose the following question to ourselves: *if the student could only modify one thing next time, which change will result in the most significant improvement?*

- **Actionable:** feedback is provided with the aim of improving a behavior or task, emphasizing what can be done better next time. Students need to get the message that ability is not fixed but incremental, and that it can be improved by practicing. If students think that the ability is fixed, those that are not confident with the task would rather be thought lazy than stupid and they will avoid doing the task[13].

- **Timely:** in order to be useful, feedback has to be provided at the right time. If the feedback arrives too late, there is no option to improve the task neither to incorporate the learnings from the feedback in future work.

- **Respectful:** no one knows everything; we all can improve. Feedback is not a judgement of the person but information about how to improve a task. However, the way feedback is delivered can impact the classroom climate and create defensiveness on the students. In order to avoid that, feedback should be honest and kind, offering help on how to improve. In some cases, it should be given privately to avoid comparisons with the other classmates.

3.4. Peer-assessment and self-assessment

Peer assessment is the process in which students assess their peers work based on teacher's criteria. Peer assessment develops metacognitive skills by allowing them to critically evaluate a piece of work. It has been argued that the act of applying assessment criteria to evidence such as essays, reports, presentations, and so on is a much deeper learning experience in itself that just reading or observing the assessment tools[14].

However, peer assessment also offers some challenges, and most of them are associated with the difficulties students experience when receiving feedback from their classmates, who they consider in-experts and not sufficiently objective. On the other hand, the students giving the feedback might also feel they don't have the expertise required to give feedback on their peers' work.

To effectively use peer assessment, teachers need to have very clear and explicit assessment criterion (i.e. rubric). Students also need to understand why they are being involved in this process and how it is going to benefit them (both assessing a piece of work, and receiving feedback/suggestion from someone that is at their same level of understanding). Making peer assessment anonymous will facilitate the process.

Self-assessment is a very similar process in which students use the assessment criteria provided by their teachers to assess their own work. This allows students to reflect on their own learning, and can develop skills related to life-long learning. Students gain the habit of judging their work, and do not take success for granted.

Both peer and self-assessment help interiorizing the learning goals in a much more effective fashion. They are also useful to compare the perception that the teacher has of the students' work with the students' perception.

4. Context

In this section I will make a brief description of the school, the program and the student group for which the unit is planned.

The school selected is an international school, and the project is designed to fit such a school. As specified in the "Real Decreto 806/1993 (28 de mayo)"[15], the International schools in Spain are allowed to follow other curriculums as long as they offer Spanish History and Spanish Language and Culture. Therefore, even though the school described is located in The Netherlands, this work could apply to any international school located in Spain.

4.1. Location and facilities

The American International School of Rotterdam (AISR) is a non-profit private school that was founded in 1959. Located in Rotterdam, The Netherlands, AISR is nestled in a quiet neighborhood called Hillegersberg, where students can easily access the school by foot or by bike. Its facilities include:

- Library
- Multimedia Center
- Art room
- Music and Band rooms
- 3 Science Labs
- Double Gymnasium
- Sports fields
- Swimming pool (off site)
- Canteen
- Infirmary with a School Nurse
- Interactive classroom screens
- MS/HS 1:1 laptop program (each student has its own laptop)

4.2. Education

The American International School of Rotterdam provides an English language education. The curriculum is American in nature, but modified to provide an international perspective, for students from a wide range of nationalities and cultural backgrounds. AISR is accredited by the Council of International Schools (CIS) and the New England Association of Schools and Colleges (NEASC). It offers a variety of curriculums including the International Baccalaureate Diploma Program (IBDP), the

International Primary Curriculum, (IPC) and the International Middle Years Curriculum (IMYC). This project will be designed around the IMYC, more specifically in Grade 8.

AISR offers education for students from Pre-Kindergarten through Grade 12. The school is divided in three sections:

- Early Learning (Pre-K1 and Pre-K2)
- Elementary School (Kindergarten to 5th grade)
- Secondary School (6th-12th grade), in which the TFM will be based.

The Secondary School is organized into two divisions: Middle School (grades 6-8) and High School (grades 9-12).

English is the language of instruction at the school. All classes, except for the modern language classes, are conducted in English and use native language resources. English as an Additional Language (EAL) support is available for all students in Grades K–10 whose first language is not English and need additional language support because of their language background.

The following subjects are offered: English Language Arts, Modern Languages (which include Dutch, Spanish, Italian, Russian, German, French, Chinese and Japanese), Mathematics, Science, Social Studies, Arts (Music, Art and Drama), Information and Communication Technologies and Physical and Health Education.

4.3. Students

The total school enrolment is approximately 220 (for grades from PK1-12). Almost half of the students are Dutch, American, Japanese or Indian, and the remaining 50% includes more than other 20 nationalities.

This project will be focusing on Grade 8. Grade 8 has a total of 14 students: 2 Dutch, 1 French, 3 American, 1 Brazilian, 1 Indian, 2 Finns, 1 German, 1 South African, 1 Norwegian and 1 Korean. They are all 13-14 years old and come from very different backgrounds. Only 3 of them are English native-speakers, but besides 2 students receiving EAL support, the rest of the class can function perfectly in English. One EAL assistant is present in their Science lessons in order to support the students that struggle with the English language. Four students receive Learning Support services (2 of them being the students receiving EAL support), which means that an Educational Assistant (EA) is also present in Science in order to support the students. These students have different needs, but in general all of them need further explanation, support when taking notes, guidance when working in the lab, etc. Generally, in the Science class, there are a total of 3 adults in the room: the Science teacher, an EA to provide learning support to the students mentioned above, and an EAL assistant.

There are no behavioral problems in this class; the school in general has little problems regarding bullying or exclusion. Students are used to being surrounded by different cultures, and are in general very accepting and tolerant. Unlike the general trend, these new teenagers show little disruptions and are engaged and attentive to the tasks on hand. Since the group was very small last year (only 8 students), they are all very inclusive, and seek for new friendships. Even though a few students leave and arrive every year, they are all welcoming and very supportive of each other.

4.4. Science

AISR, as mentioned before, follows the International Middle Years Curriculum[16] in its Middle School Section. The Science program is an Integrated Science program in which Biology, Chemistry, Physics and Earth Science are taught during the course of 3 years. The main aims of the Science program are to encourage and enable students to:

- understand and appreciate science and its implications
- consider science as a human endeavor with benefits and limitations
- cultivate analytical, inquiring and flexible minds that pose questions, solve problems, construct explanations and judge arguments
- develop skills to design and perform investigations, evaluate evidence and reach conclusions
- build an awareness of the need to effectively collaborate and communicate
- apply language skills and knowledge in a variety of real-life contexts
- develop sensitivity towards the living and non-living environments
- reflect on learning experiences and make informed choices

In grade 8, five units are taught, that will cover some aspects of the sciences mentioned above. For this TFM, I have chosen one of the units that focuses on Chemistry, and that is Unit 2 - Interpretation.

5. Unit

In this section, the implementation of formative assessment in a unit will be shown. The unit chosen is a Chemistry Unit in Grade 8; in this unit the following topics are studied: history of the atom, atomic structure, and the periodic table and periodic trends. The unit prepared contains all the elements needed for direct application in the classroom.

The unit has been designed using the following structure:

- Learning Goals
- Methodology
- Prior learning
- Unit Plan
- Activities (in which the formative assessment has been included)

5.1. Learning goals

The learning goals of this unit are divided in two groups. The first group includes the "Scientific Enquiry Learning Goals", which refer to the content and skills that are expected of a Science subject; they mostly address the Scientific Method and the Nature of Science. In the second group we can find the Chemistry Learning Goals, which include the subject specific content and skills that will be covered during the unit. Numbers associated with the learning goals refer to those assigned by the International Middle Years Curriculum.

IMYC Goal No.	Scientific Enquiry Learning Goals
4.1	Know that the study of science is concerned with investigating and understanding the animate and inanimate world around them
4.2	Be able to conduct scientific investigations with increasing rigor by being able to: • Choose an appropriate way to investigate a scientific issue • Generate a hypothesis • Gather data to test a hypothesis • Decide which data, observations and measurements are necessary to test the hypothesis, including selecting apparatus and identifying any health and safety issues • Use their scientific knowledge and understanding to predict outcome • Make systematic and accurate measurements from their observations • Draw conclusions based on the evidence • Relate the outcome to their original prediction • Explain and justify their predictions, investigations, findings and conclusions • Record and present their findings accurately using the most appropriate medium, scientific vocabulary and conventions • Repeat investigations, observations and measurements to check their accuracy and validity • Identify patterns in the results • Use scientific language to explain any differences found in the results of investigations • Suggest ways in which their investigations and working methods could be improved • Relate their own investigations to wider scientific ideas

IMYC Goal No.	Science of Chemistry Learning Goals
4.27	Know about the particulate nature, structure and properties of matter; atoms and molecules
4.28	Know about the structure and conservation of matter - materials and mass - and the total energy of a system
4.33	Know about the chemical properties of common substances

4.36	Be able to describe and illustrate an atom and its parts (nucleus, protons and electrons) using a simple model, e.g. the Dalton model
4.40	Be able to represent simple chemical reactions using formulae and equations
4.41	Be able to classify materials according to their physical and chemical properties
4.42	Be able to use the Periodic Table to identify elements, know their symbols and classify them
4.43	Be able to predict trends in chemical reactions of elements in periods and groups
4.47	Develop an understanding and appreciation of scientific models/laws that explain the fundamental nature of things and the need to remain willing to re-examine existing models

5.2. Methodology

Throughout the unit, different methodologies will be used, which will be fully described in the activities section. All of them have a few shared characteristics:

- Learners are the focus of the learning process.
- Students are given ownership of the learning process, and can reflect about it.
- Active learning is promoted both individually and cooperatively.
- Teachers are one more tool that students can use in their learning process.
- Aim to develop the learner autonomy and independence.

5.3. Prior learning

This unit is taught in Grade 8. Students in this course have studied Integrated Science for two years. Even though Chemistry has not been explicitly taught, students have been exposed to:

- The concept of atom (Grade 6, when discussing photosynthesis and the formation of glucose)
- A simple version of the model of the atom (Grade 7, Bohr model)
- The organization of the Periodic Table (Grade 7).

Prior learning is assessed when a new Learning Goal is introduced in order to guide the teaching and learning process. Different techniques will be used; all of them will be explained in the activities section.

5.4. Unit plan

Activity	Duration /minutes	Learning Goals	Materials	Brief description	Formative Assessment
#1	45	Prior Knowledge	#1 – Learning goals	Learning goals are shared and discussed with the students.	Setting learning goals Self-assessment of previous knowledge. Brainstorming – mind map
#2	45	4.28 4.33	#2 – PowerPoint presentation #2 – Note-taking sheet	Teacher presents an historical view of atomic models. Students will take notes and share their knowledge with their peers by "Reciprocal teaching"	Feedback is given to students during the reciprocal teaching activity. Exit point activity.
#3	135	4.28 4.33	#3 – Lab handout	Lab with 6 different stations in which students will learn how rearrangement of atoms affects the properties of substances.	Teacher feedback on lab skills (not on content) Peer-assessment.
#4	45	4.28 4.33	#3 – Lab handout #4 – Chemical Equation broken down	Discussion on the observations made at the lab session. Discussion about chemical reactions and conservation of atoms.	Assessment will be done in the next session: Entry ticket.
#5	90	4.28 4.33	#5 – Entry ticket #5 – Law of Conservation of Mass lab	Entry ticket to assess previous session. Learning the Law of Conservation of Mass by means of a lab.	Entry ticket. Students answers will be corrected by the teacher and feedback will be provided by comments-only (not grading)

#6	45	4.28 4.33	#6 – Vocabulary Matching pairs #6 – Vocabulary in Action #6 – FA Chemical formulas and Conservation of mass	Activities to review and consolidate learning from previous sessions.	Self-assessment (pens-down strategy). All students write their answer in a small white board. When wrong answers appear, teacher uses effective questioning that reveals the thinking progress that has led to that answer.
#7	90	4.28 4.33	Activity #7 – Quiz Test rubric	Quiz to check student skills at this point.	Students get feedback on their mastery level according to the test rubric. Students self-assess their work.
#8	45	4.27 4.36	Elements song Animation	Review of the atomic structure	Entry point on the next session.
#9	90	4.27 4.36	#9 – Clay model #9 – Reflection	Construction of clay models of the first 20 elements.	Self-assessment will be compared with teacher assessment and used to improve the models.
#10	45	4.42	#10 – PowerPoint #10 – Periodic Table cards	Importance of order and introduction to the periodic table.	Self- and peer-assessment will naturally occur while working on teams. Teacher will use the card drawing as assessment tool.

#11	90	4.1 4.27 4.47	#11 – Timeline exemplar #11 – History of the Atom timeline handout and rubric	Construction of a timeline with data about the history of the Atom	Students will assess a timeline exemplar with the rubric (example of successful task) Peer-assessment of the timelines. Teacher feedback
#12	90	4.1 4.27 4.36 4.47	Activity #12 – Rutherford's lab	Lab with marbles to help understanding Rutherford's experiment.	Questioning and classroom discussion
#13	45	4.36 4.42 4.43	Activity #13 – Periodic trends: Straw lab	Visual representation of periodic trends (atomic size, ionization energy and electronegativity)	Teacher will correct the lab handout and give comment-only feedback
#14	90	4.27 2.28 4.33 4.36 4.41 4.42 4.42 4.44 4.47	Activity #15 – Atomic structure Quiz Test Rubric	Final Quiz reviewing all the unit	Teacher will correct the quizzes and give back them to the student indicating their mastery level according to the test rubric

5.5. Activities

In this section, the 14 different activities that form the Unit will be discussed. Each activity will include 4 different aspects:

- Learning goals pursued with that activity.
- Materials prepared for its use in the classroom, which can be found on the annexes.
- Description of the activity and how it will be implemented on the classroom.
- Assessment of the activity, pointing out the integration of formative assessment.

Activity #1

#1 Learning Goals
Determine prior learning

#1 Materials
Activity #1 – Learning goals

#1 Description
Learning goals are distributed to the students. After all students have read the goals, they are discussed to ensure that all the students fully understand them. If needed, goals will be re-phrased in a more student-friendly language. This step is crucial as teacher is trying to get as much information as possible about what they already know. This handout includes a self-assessment table, where students will select the level where they think they are at (Never seen before/Sounds familiar/Studied before).
Once this is completed, a brainstorm activity is carried out. Students are asked to think about concepts, words, examples, skills, etc. that are related to the standards they have been given. At this point, all students should be able to contribute with at least a couple of ideas, but teacher should not expect a formal knowledge of this topic. In order to ensure that all students participate, the teacher will use the "Popsicle Stick" technique: all students are asked to write their names in a Popsicle sticks and all the sticks are then placed in a cup. The teacher will randomly draw a stick from the cup and the student whose name is on the stick will answer the question. This will continue until all students have been called out. This technique sets the expectation that all students are worth hearing, and avoids the stress that some students experience when they don't know the answer, but the rest of students are raising their hands to participate. The teacher will record the information on the board in the form of a mind map, trying to organize the knowledge in the space given (for example, concepts that are most closely related will be placed together on the board and away from other topics). The teacher will ask questions looking for connections between the different ideas presented by the students.

#1 Assessment
During this introductory activity, students self-assess their prior knowledge by filling out their level in each of the learning goals of this unit. At the same time, the teacher becomes familiar with the students' prior learning, and must modify the lesson plan accordingly.

#1 Notes

By having students assess themselves, we are encouraging them to be owners of their own learning process. They become aware of what they know, and the direction they will be moving forward. The expectations are clear for the whole class.

Activity #2

#2 Learning Goals

4.28 Know about the structure and conservation of matter - materials and mass - and the total energy of a system.

4.33 Know about the chemical properties of common substances

#2 Materials

Activity #2 – PowerPoint presentation[a]

Activity #2 – Note-taking sheet

#2 Description

A digital presentation is used to discuss the history of the development of the understanding of the atom model we use today; it will also help students understand how and why scientists interpreted their findings in the way they did (Activity #2 – Powerpoint presentation). The students are encouraged to participate in the presentation by sharing their knowledge. Students are given a note-taking sheet, where only some of the names of the scientists in the presentation appear (there are 2 different note-taking sheets, with different scientists on them). They are asked to take a few notes on those scientists, describing their major accomplishments.

After the presentation, students will use the "Reciprocal Teaching[b]" technique to share their knowledge. Students are seated in pairs, making sure that the two students in the pair had different note-taking sheets. One student is A, the other is B. Students are asked to imagine that their partner just arrived and missed the information that was just presented. Student A's task is to teach his notes to student B, and vice versa. As this happens, the teacher listens to as many pairs as possible, making sure that the information given is correct and clarifying if needed.

At the end of the lesson, students are asked to go back to their seats, and to share something they learnt during the lesson. They will do this using a real-time questioning technology (www.socrative.com). The teacher will select the "Exit Point" activity, in which students are asked the following questions:

- How well did you understand today's material?
- What did you learn from your classmate in today's class?
- What did you teach in today's class?

If time is too short, this last activity can be completed as homework

#2 Assessment

There are two different assessment moments in the activity:

- Checking for understanding as the students are teaching their classmates. The teacher will clarify any misunderstandings, but students are not supposed to master this content yet.

[a] Adapted from: education.jlab.org/jsat/powerpoint/atomos.ppt

[b] http://pdfs.cpm.org/studyTeam/Intro_Study_Team_Support.pdf

- Sharing feedback on the Exit Point. Feedback will be delivered to all students and will guide their learning and encouraging them to be more proactive in the learning process. At this point, feedback will be mostly focused on guiding learning behaviors, and not so much on content.

#2 Notes:
Socrative is a real-time questioning tool, freely available on-line. It allows teachers to assess their students as learning happens. Teachers can see everyone's information on their screen, getting a general idea of the class performance, but can also access one specific student or one specific question. These are some of its features:

- Instant feedback: answers can be seen on teacher's screen as soon as students respond.
- Personalized content: Teacher can use questions from the database or design specific assessments for his/her students.
- Reports: reports are generated automatically both in pdf and excel formats, helping to keep the track on student's performance (both individually and as a group).

Activity #3

#3 Learning Goals
4.28 Know about the structure and conservation of matter - materials and mass - and the total energy of a system.
4.33 Know about the chemical properties of common substances

#3 Materials
Activity #3 – Lab handout

#3 Description
In today's activity, students carry out different chemical reactions in stations that illustrate the idea that the rearrangement of atoms has an effect on the properties of substances. There will be six different stations (one reaction performed per station; **experiments have to be set up before class starts**). Students will be grouped in pairs or groups of 3, so there are 6 groups in total. Each group will be given the handout and assigned a station. After the experiment is finished, the groups will rotate until all groups have been in all six stations. Students are to follow the instructions given in the handout and to record observations before and after the experiment. The observations should include color, smell, texture, temperature and any other physical properties they observe. It is very important that students note the differences between the reactants and the products.

These are the general instructions for the experiments:

- Station 1: electrolysis of water to decompose into its basic elements hydrogen and oxygen. Test each gas to show that one is oxygen and the other one is hydrogen:
    - Oxygen: place a glowing splint into the test tube and it should relight.
    - Hydrogen: place a burning splint into the test tube and you will hear a squeaky pop.
- Station 2: formation of magnesium oxide. Using a Bunsen burner take a 4cm piece of magnesium and burn it until it lights. Warn students not to look directly at the light because it could blind them.

- Station 3: Dehydration of sugar with acid: **to be carried out in the fume hood** (because of the fumes that will be released in the reaction). Measure 5 g of sugar into a boiling tube, and then carefully pour 2.5 ml of concentrated sulfuric acid into the boiling tube. It will take several minutes for the reaction to happen, but the results are very drastic.
- Station 3: Displacement reaction. In a boiling tube pour 2 ml of silver nitrate, then take a piece of copper wire and twist it so that it fits into the boiling tube but can be lifted out of the boiling tube.
- Station 4: Precipitation reaction. Pour 2 ml of silver nitrate into a boiling tube, then pour 2 ml of potassium iodide and observe the dramatic color change.
- Station 5: Redox reaction. Mix 30 ml of a potassium iodide saturated solution with some dish soap in a large tall heat resistant container. Add 10 ml of 30% hydrogen peroxide to the KI. The reaction will be messy (contain everything in a big bowl) and will release heat.

These reactions will demonstrate what happens when atoms in a substance are rearranged to form another substance.
After the experiments, the teacher will use a diagram[c] to show what happens to the atoms inside two reactants when they react to create a product. Using the first two reactions as an example, the following ideas will be pointed out:

- The substances that react together are called the reactants.
- The substances that are formed are called the products.
- Products have different properties from the reactants
- Chemical reaction notation: reactants → products
- As a reaction takes place, atoms in the reactants are rearranged to form the products.
- The number of atoms of each element in the reactant is the same as in the products (no atoms are added or subtracted) – conservation of atoms

Students will draw diagrams (showing the atoms in each molecule, and the number of molecules of reactant and products) to represent the remaining four reactions.

#3 Assessment
Previous to the lab session, the teacher will choose 2-3 lab skills that will be assessed during the activity. Some of the skills are: lighting a Bunsen burner, use of a scale, measuring volumes, proper use of protective equipment, etc. The teacher will communicate to students which skills will be assessed and feedback will be given to students during the lab session. Only 2-3 skills will be assessed at a time to avoid overwhelming students.
The diagrams drawn by the students will be checked in class. The teacher will solve each reaction on the board. In pairs, the students will swap their papers, to correct their peer's work (peer-assessment). This will show the students the point of having a world-wide known notation system, so scientists from different countries can understand each other's work. Corrections will be made on the paper and returned back to their peer.

[c] https://dr282zn36sxxg.cloudfront.net/datastreams/f-d%3A7a62c222a9fecbc25c5a106f0f62e008dea2ed3b423fdcb669d1c959%2BIMAGE_THUMB_POSTCARD%2BIMAGE_THUMB_POSTCARD.1

#3 Notes
Peer assessment is used in this activity for different reasons:

- Students are exposed to diagrams that might be different than theirs, realizing of the importance of using common notation systems.
- Students assessing can learn from their peer's work and improve his diagram accordingly.

Activity #4

#4 Learning Goals
4.28 Know about the structure and conservation of matter - materials and mass - and the total energy of a system.
4.33 Know about the chemical properties of common substances

#4 Materials
Activity #3 – Lab handout
Activity #4 – Chemical Equation broken down

#4 Description
The observations recorded in the lab handout will be briefly discussed in class. After that, teacher will pair students and with the aid of the website provided[d] have them answer the following questions in their notebooks:

1. What is a compound?
2. What is a chemical formula and what does it tell us?
3. What do the numbers in a formula mean?
4. What do the numbers in a chemical equation mean and how do they relate to the numbers in the formulas?
5. What is a coefficient in a chemical equation?
6. What is a subscript in a chemical equation?
7. What happens to the atoms of the reactants during chemical reactions?

After they have answered the questions, teacher shows the *Activity #4 – Chemical Equation broken down* document and uses that to discuss students answers as a class discussion. Again, the fact that the number of atoms of each element should be the same for reactants and products is pointed out (conservation of atoms).

#4 Assessment
Teacher can assess what students have learned by performing the lab activity during the class discussion.
Evaluation of the concepts learned during this activity will be assessed at the beginning of the next class, using a formative assessment tool called "Entry ticket"[17]. This will be done by using the quick question option on Socrative. Students will answer a couple of questions about the topic they have seen today (it should not take longer than 5 minutes), and the lesson plan for that day will be designed around the fact that information on the student learning will be coming in at the start of the lesson.

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[d] http://www.bbc.co.uk/schools/gcsebitesize/science/21c/air_quality/chemical_reactionsrev1.shtml

Activity #5

#5 Learning Goals
4.28 Know about the structure and conservation of matter - materials and mass - and the total energy of a system.
4.33 Know about the chemical properties of common substances

#5 Materials
Activity #5 – Entry ticket
Activity #5 – Law of Conservation of Mass lab[e]

#5 Description
Students complete the Entry Ticket activity on Socrative. When Entry Tickets have been submitted to the teacher, students, in pairs, start working on the Law of Conservation of Mass lab. Despite working in pairs, each of the students has to fill all the sections of the lab handout by its own. Details on the activity can be found in the appendices.

#5 Assessment
Students will answer the Analysis and Results, and Conclusion sections and will hand them in to the teacher. These answers will be assessed and feedback will be given in the form of comments on the handout (without a grade). Students will make corrections based on the feedback, this will be submitted to the teacher.

#5 Notes
The Entry Ticket activity is used to assess and recall learning from previous session but also helps to make students active and participative as soon as they enter in the classroom.

Activity #6

#6 Learning Goals
4.28 Know about the structure and conservation of matter - materials and mass - and the total energy of a system.
4.33 Know about the chemical properties of common substances

#6 Materials
Activity #6 – Vocabulary Matching pairs
Activity #6 – Vocabulary in Action
Activity #6 – FA Chemical formulas and Conservation of mass

#6 Description
The goal of today's lesson will be to review and consolidate students' learning.
Lab handouts are given back with feedback on them, and students are given a couple of minutes to look at it. After that, answers are discussed as a group. Students will make corrections based on the feedback and discussion, and they will submit the work again.
A vocabulary matching activity is then handed out to students, who working in groups of 2-3 will have to find the matching pairs. Once the teacher checks that their matching is right and in the

[e] Adapted from:www.middleschoolscience.com

same groups as before, students write their own definitions of the words in the cards without looking at the cards.
After that, students complete the Vocabulary in Action worksheet as a review activity. At this point, students should feel comfortable with the content, as there have been several learning opportunities. A KEY is left on one corner of the room, and students can go and check their answers against it, but they will not be allowed to have any writing utensils with them. They will need to go back to their seat and then correct their answers (pen-down strategy). After that, they will be allowed to check their answers once more. To end today's lesson, a formative assessment technique will be used to check for understanding. A power point presentation with questions is presented to the students. Each student has an A4 whiteboard and a marker, and will answer the question presented to him/her on the whiteboard. Once all students have answered, they show their answers to the teacher by holding their whiteboards up in the air. If there are no wrong answers, the class moves on to the next question; if there are incorrect answers, those are discussed with the students, looking for the reasoning that leads them to that answer and the reasons why those might not be correct.

#6 Assessment

Students will self-assess their Vocabulary in Action worksheet by the pen-down strategy. By not allowing students to copy the right answer directly, we promote careful reading and analysis of the answers.
By using the whiteboard activity, the teacher can quickly get an idea of how the students are doing, and then use that in the design of the future lessons. The students seem to receive this type of activity very eagerly, and become very enthusiastic about it. Since the rest of the students don't see their answers, students feel comfortable sharing them.

#6 Notes

Different individual activities are planned for the day, so students can work at their own pace. Only the matching activity and the whiteboard activity are essential, so if some students do not have an opportunity to complete the Vocabulary in Action worksheet due to a slow pace, they will skip that one, as it is review, but does not provide any new content.

Activity #7

#7 Learning Goals

4.28 Know about the structure and conservation of matter - materials and mass - and the total energy of a system.
4.33 Know about the chemical properties of common substances

#7 Materials

Activity #7 – Quiz
Test rubric

#7 Description

Students take a quiz on the content they have seen so far.

#7 Assessment

Students will not be given a single numerical grade neither specific comments; instead, only the mastery level will be described according to the "Test Rubric". After the teacher returns the work, and knowing in which state of learning they are, students will make corrections (self-assessment) on the quiz using a different color pen. This also helps students get an idea of the general mastery level just by looking at the predominant color in the quiz.

#7 Notes

The rubric allows for more specific feedback for the students. When they are given a single grade, students don't know which areas they still need to work on, or which areas they excel at; by using descriptors, we are telling the students what we are expecting from them.
At this point, no specific comments are given about the quiz, to promote student effort to self-assess his work with the rubric.

Activity #8

#8 Learning Goals

4.27 Know about the particulate nature, structure and properties of matter; atoms and molecules
4.36 Be able to describe and illustrate an atom and its parts (nucleus, protons and electrons) using a simple model, e.g. Dalton model

#8 Materials

Elements song: https://www.youtube.com/watch?v=d0zION8xjbM
Animation: http://www.kscience.co.uk/animations/atom.htm

#8 Description

The goal of today's activity is to review the atomic structure. Students have seen this before, so most of the lesson will be spent practicing drawing models for different elements.
First, the "Elements song[f]" is played, just to introduce students to the diversity of chemistry.
After that, each student is given a Periodic Table, and with the knowledge they already have, and the support from the teacher, the following points are discussed:

- Protons
- Electrons
- Neutrons
- Atomic number
- Atomic mass

This information should be recorded in their notebooks. Students are encouraged to find out what the periodic table tells them about the above points. For instance, the number of protons of an element is given as the Atomic Number, and the number of electrons is the same as the number of protons, since the atom is neutral. The notation used in the periodic table must be explained and recorded in their notebooks. The atomic structure is also discussed.
Finally, students will draw the atomic structure for the first 20 elements of the periodic table, with the help of this animation[g]. Their diagrams will include the symbol with proper notation of the atomic number and the atomic mass.

[f] https://www.youtube.com/watch?v=d0zION8xjbM

#8 Assessment
Entry point: At the beginning of the next lesson, students will be given an element, for which they will have to draw the atomic structure; they will be allowed to use the periodic table. The diagram should include symbol, atomic number, atomic mass, number of electrons and number of protons.

#8 Notes
The animation provided is very helpful for the following reasons:

- Students can choose between building the atom themselves or choosing an element for which the atomic structure is shown. This way, if they struggle at the beginning, they can see a few examples of how it is done, before they start building it themselves.
- The animation requires students to drag the protons, neutrons and electrons to their specific location (proton and neutrons in the nucleus, electrons in their specific energy level). A message will show up if students place them incorrectly.
- As students add atomic particles, the animation names the element (even in ionic form), so students can see that the elements change as the number of protons changes; they can also see that the same element can have different number of neutrons (isotopes are not formally introduced yet, but they get a general idea); finally, they can also see that by adding and subtracting electrons the element does not change, but its charge does (again, not formally introduced, just mentioned)

Activity #9

#9 Learning Goals
4.27 Know about the particulate nature, structure and properties of matter; atoms and molecules
4.36 Be able to describe and illustrate an atom and its parts (nucleus, protons and electrons) using a simple model, e.g. Dalton model

#9 Materials
Activity #9 – Clay model
Activity #9 – Reflection

#9 Description
Clay models of the atomic structure of the first 20 elements will be built. Each student will build a clay model of the atomic structure of 1 or 2 elements of their choice (advanced students will do two, students who are struggling with this might have time for only one model). In order to avoid repetition, students will sign up on the Atomic Structure Sign-Up document what will be shared with them using the GoogleDocs technology.
All students will use the following color code:

Red = electrons　　**Yellow** = neutrons　　**Green** = protons

The instructions and rubric are provided on Activity #9 – Clay model

[8] http://www.kscience.co.uk/animations/atom.htm

After that, students will complete a reflection activity. The goal of this activity is to have students reflect on the accuracy of models, and on how useful they are to humans, even though they might not be showing the reality as we know it. Students will complete this reflection digitally. This activity will not be graded as it is thought for students to reflect on their learning, but it not assessing any specific learning goals.

#9 Assessment
Students will assess their model using the rubric provided (self-assessment). The teacher will also assess the model using the same rubric and point out which criteria in the rubric was not mastered. Students need to compare teacher's assessment with their own assessment and improve their models. If students have problems to identify the points that need improvement, the teacher will then give them suggestions to guide them in the right direction.

Activity #10

#10 Learning Goal
4.42 Be able to use the Periodic Table to identify elements, know their symbols and classify them.

#10 Materials
Activity #10 – PowerPoint
Activity #10 – Periodic Table cards

#10 Description
First, pictures and examples of a chaotic situation and an ordered situation will be shown, and a discussion will be started with the students about the convenience of having things ordered.
Students will be distributed in groups of three and the teacher will then distribute the Periodic Table cards to the groups. The students will have to order them in whatever way makes sense to them; as they work on it, the teacher will encourage them to find as many trends as possible (even if they only see the patterns after having organized the cards). Even though students will work in groups, all students should be able to describe the trends when the teacher asks for justification.
The cards can be arranged: horizontally, by increasing number of figures, with the figure being the same color than the background of the card to its right; vertically, same number of figures, background with a gradient of same color; and in diagonal, same frame line.
In order to allow for differentiation, more advanced students will be given incomplete groups, to see if they can think of leaving an empty space for "missing" cards.
Once that is done, the teacher will remove a card from each group; the groups will rotate, so they are now working with a different card arrangement, and will have to draw the card that would fit in the empty space, trying to be as detailed as possible.
This activity leads into the describing how the Periodic Table was created, and the important role that Mendeleev has played in the development on Chemistry. Trends and undiscovered elements will be mentioned, but not explained in detail. The next activity will focus on deducing the trends.

#10 Assessment
The section in which students are asked to draw the card will be the assessment tool used by the teacher.

Activity #11

#11 Learning Goals
4.1 Know that the study of science is concerned with investigating and understanding the animate and inanimate world around them
4.27 Know about the particulate nature, structure and properties of matter; atoms and molecules
4.47 Develop an understanding and appreciation of scientific models/laws that explain the fundamental nature of things and the need to remain willing to re-examine existing models

#11 Materials
Activity #11 – Timeline exemplar
Activity #11 – History of the Atom timeline handout and rubric

#11 Description
The goal of this activity is to create a timeline in which students describe the History of the Atom. This will help consolidate their learning about the different scientists that participated in the development of the history of the atom, which they studied at the beginning of the unit.
First, the concept of timeline is introduced to students and a brainstorm activity is done on the board: what is a timeline, its uses, how it looks like, etc. The teacher will assess their understanding and previous knowledge.
Then, an exemplar is shared with them. Those concepts previously mentioned in the brainstorm are identified in the exemplar as a class discussion. Students are encouraged to find characteristic features of timelines. After a 10' discussion, the teacher projects on the board the rubric that they will be using to assess the exemplar (and that later will be used to assess their work). Teacher and students go over the rubric, making sure that students can come up with examples for the different criterion.
After that, students work in pairs to build a timeline of the History of the Atom. The resources they can use include their Activity #2 Note-taking sheet, the Activity #2 – Presentation and the following websites:

- http://www.chalkbored.com/lessons/chemistry-11/atomic-models-handout.pdf
- http://cstl-csm.semo.edu/cwmcgowan/ch181/atomhist.htm

The teacher will ensure that the pairs are formed so students with different Activity #2 – Note-taking sheet are working together, and therefore the group has access to all the information they recorded.

#11 Assessment
A rubric is provided for students to check their work. Before students submit their work to the teacher, the groups will swap their timelines and assess someone else's work with the rubric. Students will then have an opportunity to make correction before they submit to the teacher, who will assess the work with the rubric. Feedback will be shared with students, not only about the timeline format, but also about the content.

Activity #12

#12 Learning Goals

4.1 Know that the study of science is concerned with investigating and understanding the animate and inanimate world around them.

4.27 Know about the particulate nature, structure and properties of matter; atoms and molecules.

4.36 Be able to describe and illustrate an atoms and its parts (nucleus, protons and electrons) using a simple model, e.g. the Dalton model.

4.47 Develop an understanding and appreciation of scientific models/laws that explain the fundamental nature of things and the need to remain willing to re-examine existing models.

#12 Materials

Activity #12 – Rutherford's lab

#12 Description

Students will carry out an experiment that will help them understand how Rutherford deduced the existence of the atomic nucleus. It is an analogy to Rutherford's gold sheet experiment. Moreover, this lab will also help the students understand:

- The processes that scientists went throw to develop the model of the atom.
- The difficulties that scientists might encounter in their research, and the importance of not giving up.
- The importance of recording useful and accurate observations.
- The fact that different methods can be used to test a hypothesis, and all can be effective in achieving a common goal.

The instructions for this lab are in Activity #12 – Rutherford's lab handout.

#12 Assessment

Students will present their findings to the class – the method they chose to use and how that method was useful to find out more about the shape. Effective questioning is encouraged in this section, trying to make students create connections between their lab and Rutherford's experiment. Students should also be encouraged to reflect on the difficulties they encountered.
The questions in the lab will be discussed as a group.

Activity #13

#13 Learning Goals

4.36 Be able to describe and illustrate an atoms and its parts (nucleus, protons and electrons) using a simple model, e.g. the Dalton model.

4.42 Be able to use the Periodic Table to identify elements, know their symbols and classify them.

4.43 Be able to predict trends in chemical reactions of elements in periods and groups.

#13 Materials
Activity #13 – Periodic trends: Straw lab[h]

#13 Description
The goal of this activity is to show the periodic trends related to the following physical and chemical properties: atomic size, ionization energy and electronegativity. Students will carry out a lab in which they will create a visual representation of those trends, based on the data provided. The task is outlined in Activity #13 – Periodic trends: Straw lab.

#13 Assessment
Teacher will correct the answers to the lab handout and give them back to the students as comments-only.

Activity #14

#14 Learning Goals
4.27 Know about the particulate nature, structure and properties of matter; atoms and molecules

4.28 Know about the structure and conservation of matter - materials and mass - and the total energy of a system

4.33 Know about the chemical properties of common substances

4.36 Be able to describe and illustrate an atoms and its parts (nucleus, protons and electrons) using a simple model, e.g. the Dalton model

4.40 Be able to represent simple chemical reactions using formulae and equations

4.41 Be able to classify materials according to their physical and chemical properties

4.42 Be able to use the Periodic Table to identify elements, know their symbols and classify them

4.43 Be able to predict trends in chemical reactions of elements in periods and groups

4.44 Be able to describe and predict the reactivity of metals with oxygen, water and dilute acids

#14 Materials
Activity #14 – Atomic Structure
Test Rubric

#14 Description
Students take a quiz on the content of this unit.

#14 Assessment
Students will not be given numerical grades; the mastery level will be described according to the "Test Rubric".

[h] Adapted from: www.lachsa.net

8. Conclusions

In the following section I will discuss the conclusions reached with this master thesis. The didactic Unit presented in this work is ready for implementation in the classroom. However, we have to keep in mind that changes on both unit plan and/or activities might be needed in order to adapt the unit to the students' learning progress. All the different techniques included in the Unit were chosen based on their proven effectiveness according to literature, teachers' personal communications or my own observations on teachers applying some of these techniques in their lessons.

The formative assessment techniques that have been proposed differ on the kind of information that they provide about the learning process and also on how they help improving it; however, all of them share one common feature: they provide information at the right time and can (and must) be used to tailor instruction. Therefore, the Unit scheduled is rather a guideline than a fixed plan, and it will need some adaptations depending on the students' prior knowledge, skills and learning pace.

The main results expected from the use of formative assessment are:

- *Assessment is immediate:*
  The use of white boards or the Socrative software (among other tools), allows the teacher to recognize the level of understanding of the students in real-time. This information is crucial to set the pace of instruction and modify instruction when needed.

- *New knowledge is integrated on previous knowledge.*
  This is the base of the cognitive theory [18]. Formative assessment allows the teacher to identify the students' previous knowledge of the students as well as how the new knowledge is incorporated. Identifying students' knowledge is the main goal of some of the incorporated assessment techniques (i.e. entry ticket, exit ticket, self-assessment on previous knowledge). The teacher can therefore modify the sessions to relate the new subject with what students already know and to correct possible misconceptions. Activities like vocabulary matching, in which students have to rephrase definitions to their own words, also help students to relate the new concepts to the ones they already know.

- *Students are aware of their progress.*
  Students' motivation generally depends on their interest about the subject of study. When students are aware of their improvements, they start to be motivated about the process of learning itself, this resulting in increased achievement. This has been repeatedly observed by the teachers on the science department at AISR. Students that did not show special interest about scientific subjects increased their motivation after tracking their learning progress and self-reflecting on their improvements. Self-assessment, entry tickets, exit tickets or mastery levels will help students to determine their knowledge and how it develops during the unit.

- *Students are not afraid of making mistakes.*
  Students always have the chance of improving their assignments after receiving feedback, and they can re-submit their work as many times as they need in order to meet

stablished goals. Multiple submissions are allowed during a defined time frame and, when grades need to be given (i.e. end of the term), only the final version will count. Therefore, students are no longer afraid of failing in their first attempt and are more prone to be creative and to perform all tasks, even when they are not fully confident with them. An AISR student said: *"I don't mind if I don't do it well the first time if I have the chance of doing it better afterwards"*

- *Students self-reflect on their work.*
  By giving only-comment feedback, students self-reflect on their work and perform better in future tasks than when they are given only grades. Some studies resulted in increased performance when only comments and no grades were provided [11], while others showed effectivity was more dependent on the type of comment independently that it was provided with or without grades[19,20]. For this unit I have chosen comment-only marking as I have observed that when students are given a numerical grade (or letter grade), they focus their attention on the grade instead of the feedback provided. By giving comments, AISR teachers have observed that students switch from asking their colleagues: *"what did you score on question x?"* to *"what did you answer on question x to reach that mastery level?/ what did you answer to cover all aspects of the question?/ how did you show evidence of this?".*

Based on research and my personal observations, the incorporation of formative assessment in the unit developed for this master thesis will result in a significant improvement in learning. Students will not only learn about the scientific topic of the unit, but they will also acquire skills related to the learning process itself, which they will benefit from in any other tasks they perform in school or in their life. I would like also to point out, that the unit also contains other learning strategies that have been proved to improve the learning process. They have not being discussed because they are not specific of formative assessment, and they are already common practice at AISR. These strategies include: learning by doing, cooperative learning or science laboratories amongst others.

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10. Annexes

In the following pages all the materials needed for implementation of the Unit are presented.

Activity #1 – Learning goals

Name:____ **Date:**____________________

TASK: These are the learning goals of the unit you are going to study. Please, read them carefully and place a tick in the column that best describes how you feel about the standard.

Code	Learning Goal	Never seen before	Sounds Familiar	Studied before
4.27	Know about the particulate nature, structure and properties of matter; atoms and molecules			
4.28	Know about the structure and conservation of matter - materials and mass - and the total energy of a system			
4.33	Know about the chemical properties of common substances			
4.36	Be able to describe and illustrate an atoms and its parts (nucleus, protons and electrons) using a simple model, e.g. the Dalton model			
4.40	Be able to represent simple chemical reactions using formulae and equations			
4.41	Be able to classify materials according to their physical and chemical properties			
4.42	Be able to use the Periodic Table to identify elements, know their symbols and classify them			
4.43	Be able to predict trends in chemical reactions of elements in periods and groups			
4.44	Be able to describe and predict the reactivity of metals with oxygen, water and dilute acids			

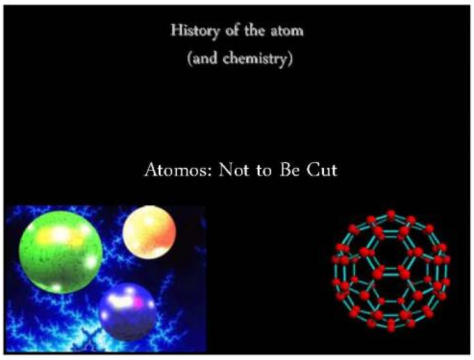
Activity #1 – Learning goals

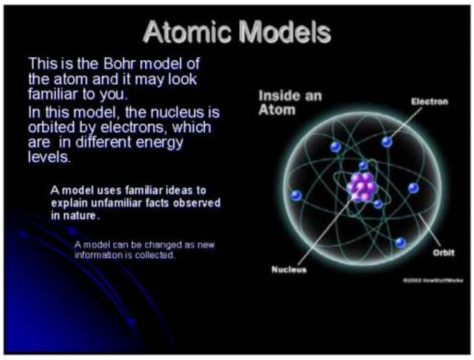
Name:____ **Date:**____________________

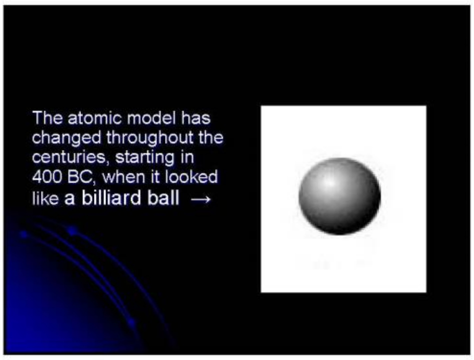
TASK: After the discussion at class, re-write the learning goals with your own words, so you can easy understand them.

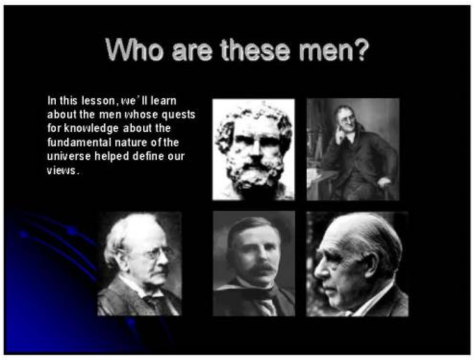
Code	Learning Goal – on my own words
4.27	
4.28	
4.33	
4.36	
4.40	
4.41	
4.42	
4.43	
4.44	

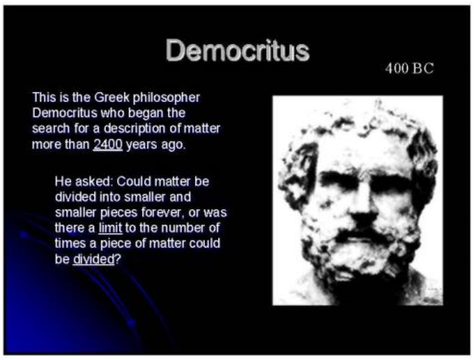
Activity #2 - PowerPoint Presentation

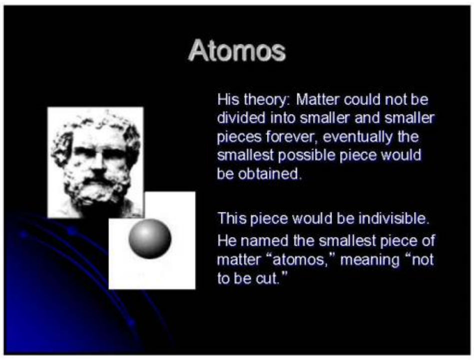












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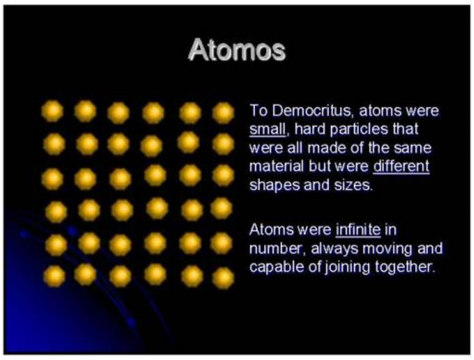

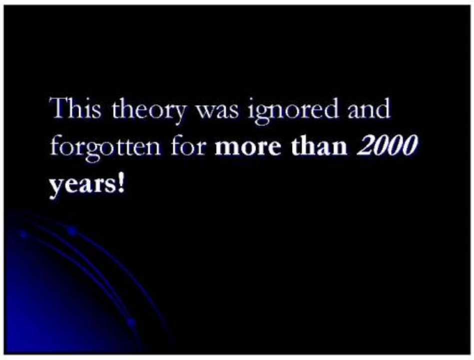

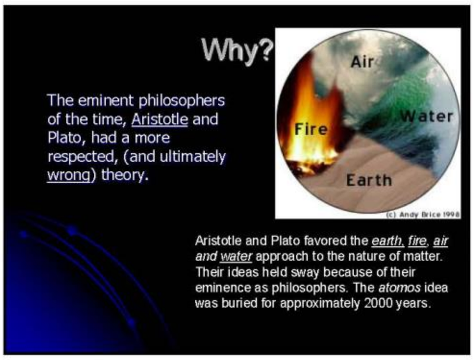

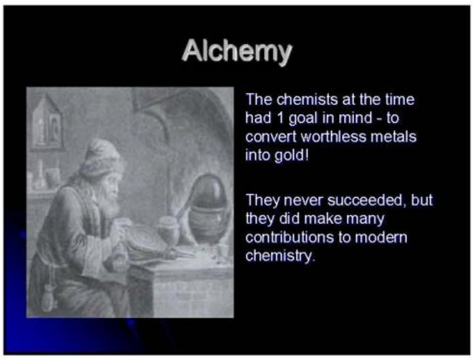

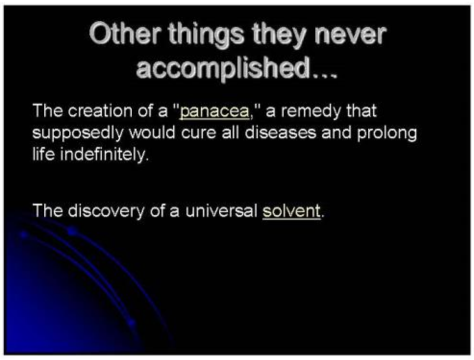

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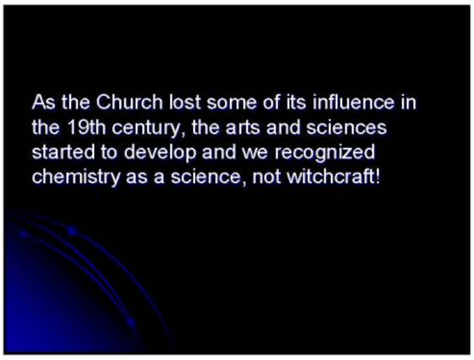

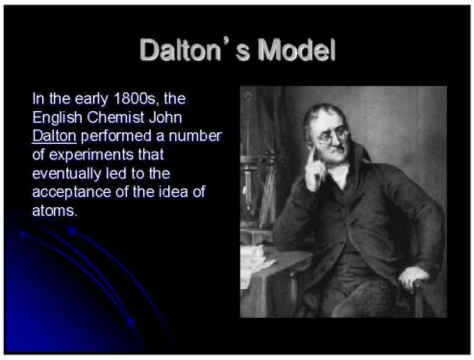

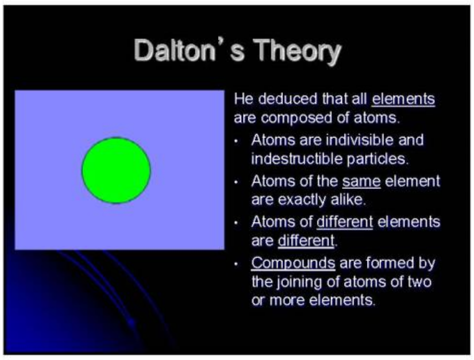

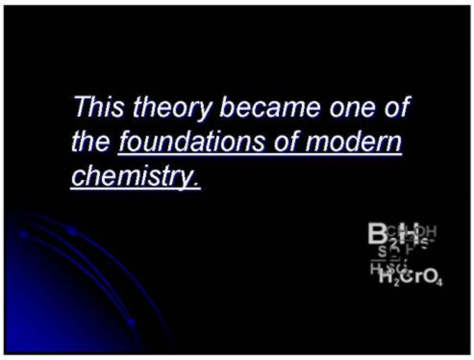

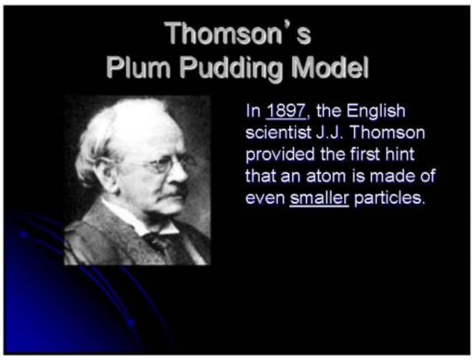

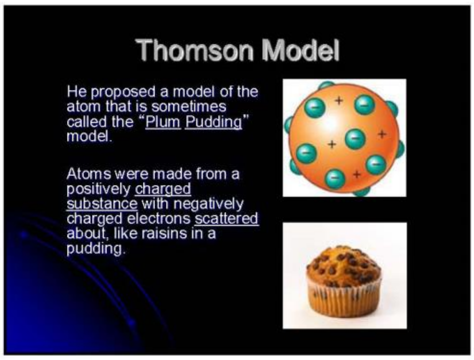

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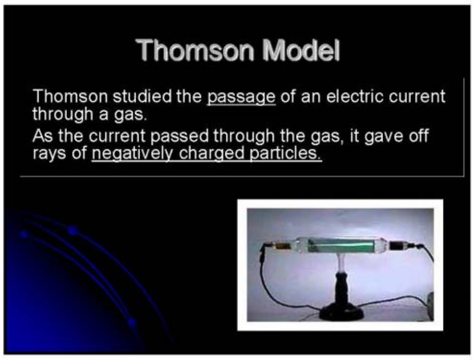

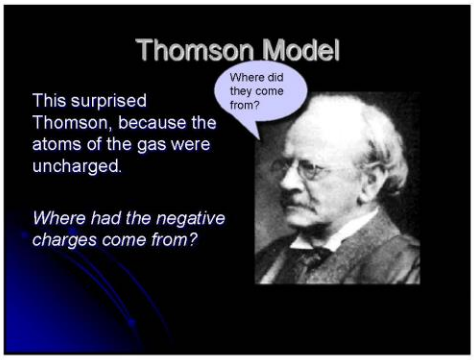

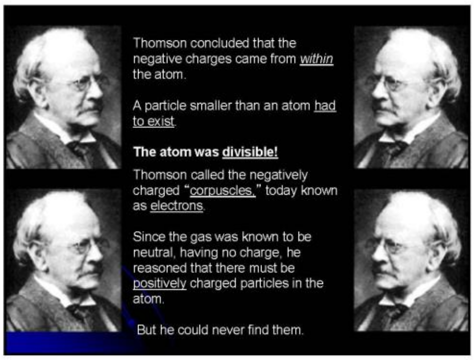

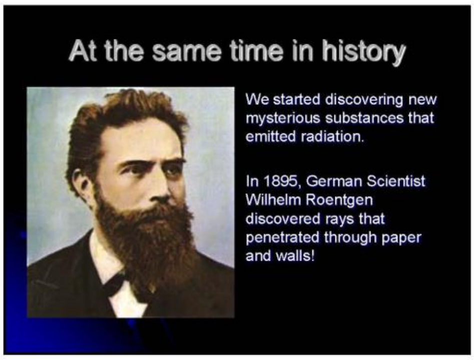

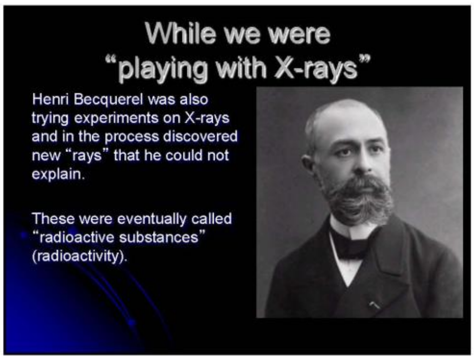

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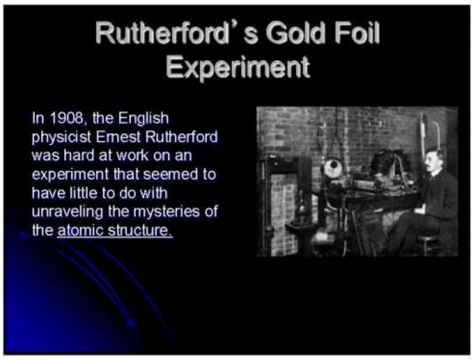

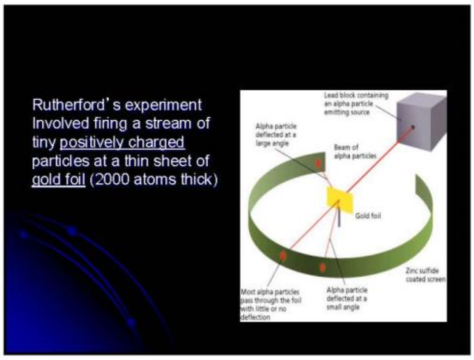

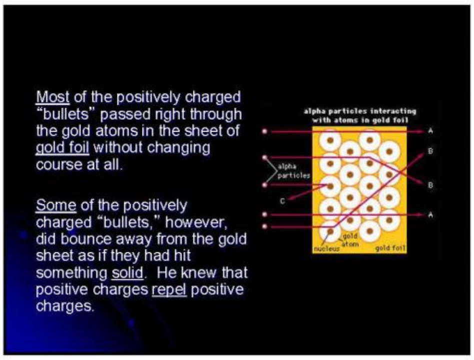

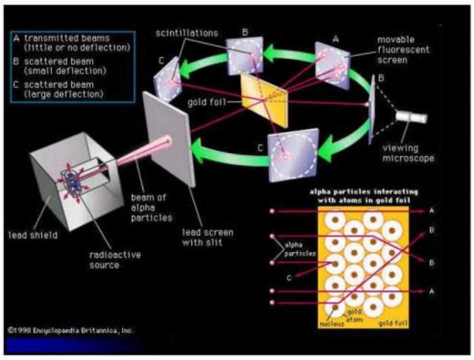

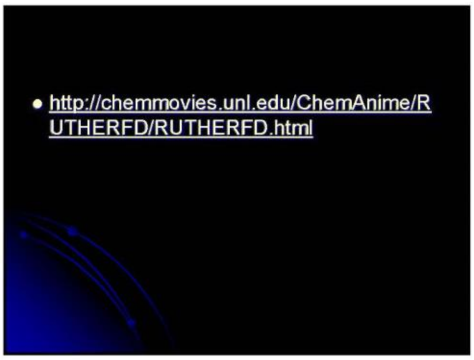

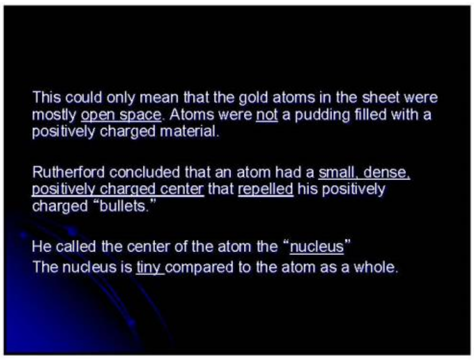

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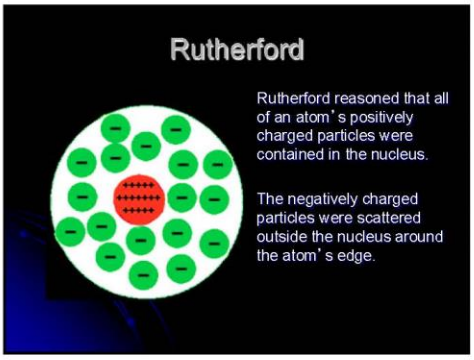

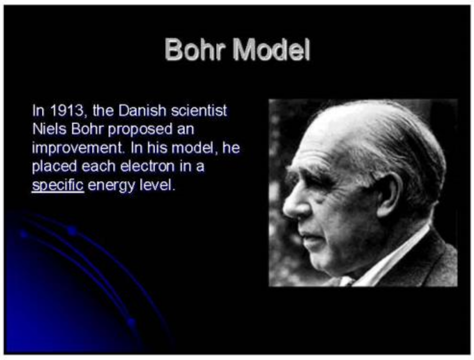

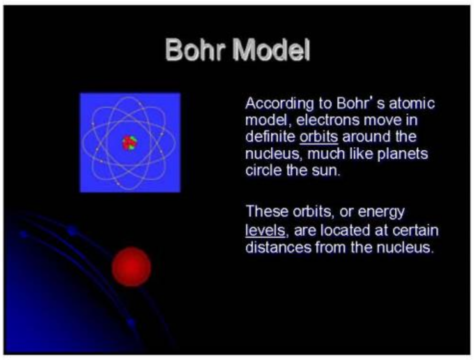

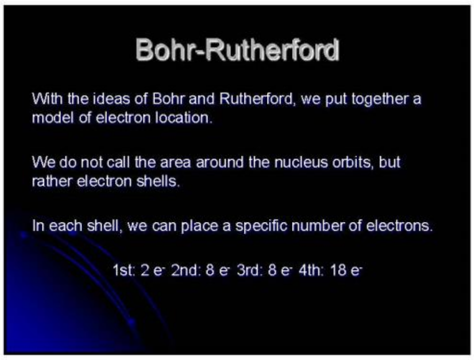

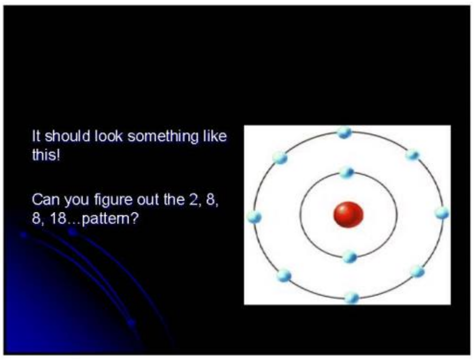

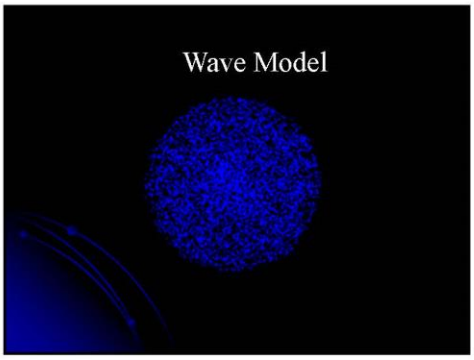

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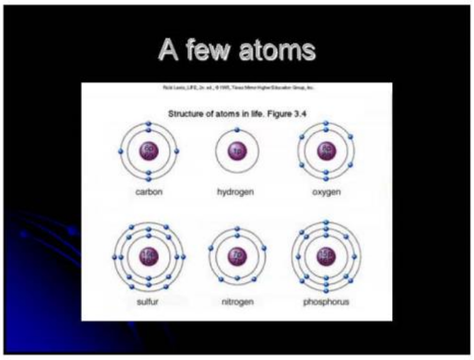

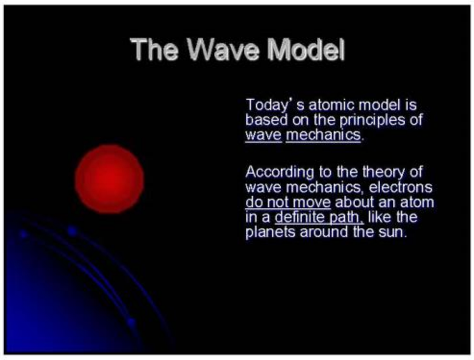

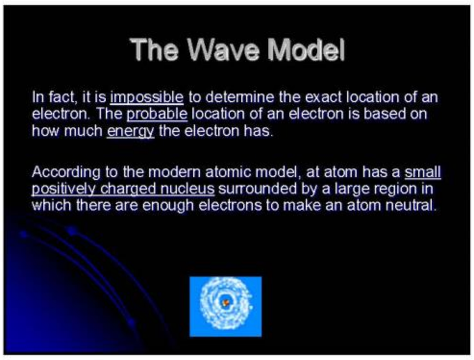

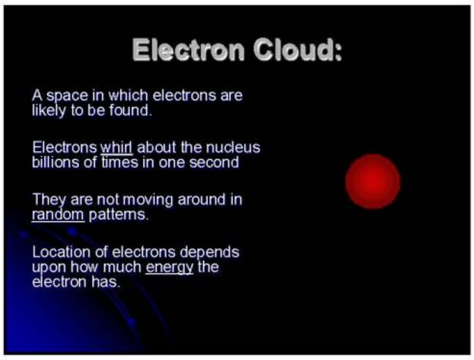

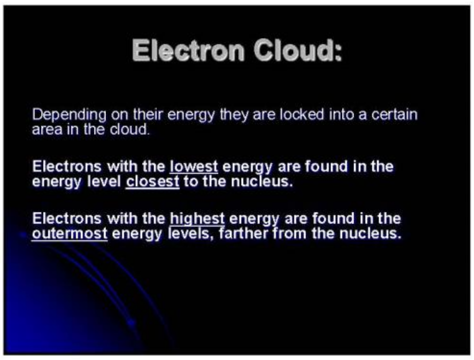

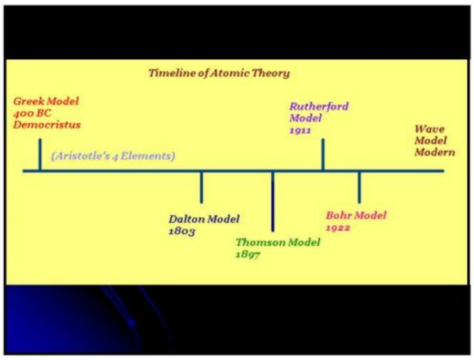

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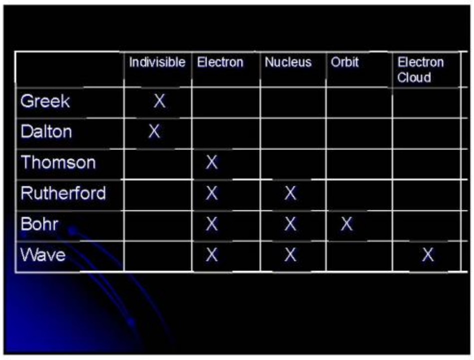
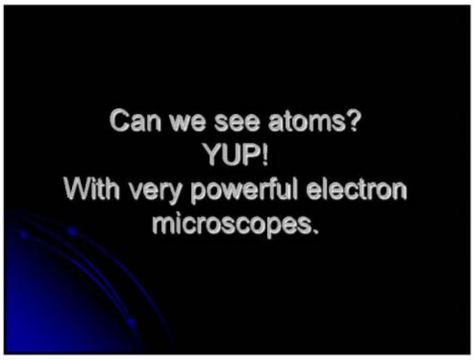
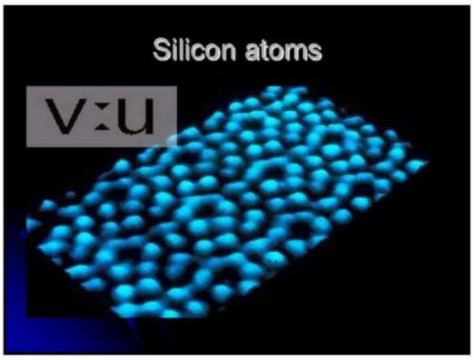
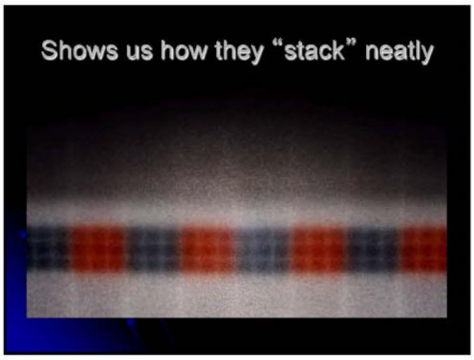
Activity #2 - PowerPoint Presentation

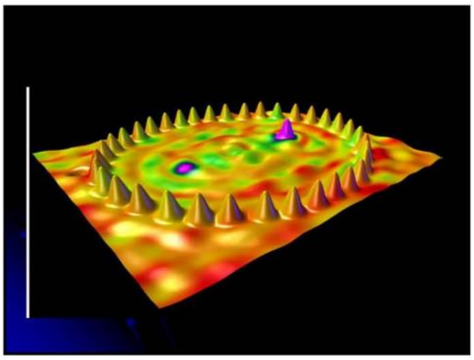


	Indivisible	Electron	Nucleus	Orbit	Electron Cloud
Greek	X				
Dalton	X				
Thomson		X			
Rutherford		X	X		
Bohr		X	X	X	
Wave		X	X		X









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Activity #2 – Note taking sheet A

Name:______________________________ **Date:**____________________

TASK: Extract information about the following philosophers and scientists from the power point presentation: When did they formulate their theories? What was their idea about the atom? How did they come up with their models?

Scientist	Information
Democritus	
Dalton	
Rutherford	
	Discovered X-rays

Activity #2 – Note taking sheet A

Name:______________________________ **Date:**____________________

TASK: Extract information about the following philosophers and scientists from the power point presentation. When did they formulate their theories? What was their idea about the atom? How did they come up with their models?

Scientist	Information
Aristotle	
Thomson	
Bohr	
	Discovered "radioactive substances"

Name:_________________________________ **Date:**____________________

Chemical Reactions illustrate that the rearrangement of atoms has an effect on the properties of substances.

TASK: You will perform a series of chemical reactions. Write down observations for each reaction.

Chemical Reaction	Safety Note	Procedure	Equation	Observations	
				Before Reaction What do the reactants look like?	**After Reaction** What do the products look like?
Decomposition of water into its gaseous elements by electrolysis		Demonstration	$2H_2O \rightarrow 2\ H_2 + O_2$		
The burning of magnesium to produce magnesium oxide	-Bunsen Burner -Do not look directly at lighted Mg (will be very bright)	1) Hold solid Mg in metal tong 2) Place in flame of Bunsen burner until it lights	$2\ Mg\ (s) + O_2\ (g) \rightarrow$ $2\ MgO\ (s)$		
Dehydration of sugar with acid	-VERY dangerous chemicals -Fumes dangerous, therefore use fume hood	1) Measure 5 g of sugar into test tube 2) Carefully pour 2.5 ml concentrated sulphuric acid into test tube 3) Wait several minutes	$C_{12}H_{22}O_{11}$ (sugar) + H_2SO_4 (sulfuric acid) $\rightarrow$ 12 C+ 11 H_2O (water) + mixture water and acid		

Name:________________________________ Date:____________________

Chemical Reaction	Safety Note	Procedure	Equation	Observations	
				Before Reaction What do the reactants look like?	**After Reaction** What do the products look like?
Displacement of silver for copper	Chemicals	1) Pour 2 ml of $AgNO_3$ (aq) into test tube 2) Wrap copper around a stick and place it in in test tube so that copper is immersed	$AgNO_3$ (aq) + Cu (s) → $CuNO_3$ (l)+ Ag (s)		
Precipitation Reaction	Chemicals	1) Pour 2 ml of $AgNO_3$ (aq) into a test tube 2) Pour 2 ml of KI (aq) into the test tube	$AgNO_3$ (aq) + KI (aq) → AgI (s) + KNO_3 (aq)		
Redox Reaction	-Chemicals -Very messy	Demonstration 1) Mix 30 ml KI with some dish soap 2) Add 10 ml 30% H_2O_2 to the KI.	$2H_2O_2 \rightarrow 2H_2O_{(l)} + O_{2(g)}$		

Name:__________________________________ **Date:**_____________________

The **"Law of Conservation of Mass"** states that when matter goes through a physical or chemical change, the amount of matter stays the same before and after the changes occur. In other words, matter cannot be created or destroyed.

Part 1: Mass Before Reaction.

Materials:

- 50 ml Vinegar
- 1 x 125 ml Erlenmeyer flask
- 1 x balloon
- Baking Soda
- 1 x funnel

1. Using your graduated cylinder, measure **50 mL** of vinegar.

2. Add the vinegar to your 125mL Erlenmeyer flask.

3. Stretch your balloon out for about a minute so that it will inflate easily.

4. Using the white plastic spoon, add **½ a bag** of baking soda to your balloon. Use the funnel to avoid spilling.

5. While keeping all the baking soda in the balloon, carefully place the mouth of the balloon over the opening of the Erlenmeyer flask to make a tight seal. The balloon will hang to the side of the flask. **Record/draw observations** (starting on page 2).

6. Using your Scale. Find the mass of the closed system. (Flask, vinegar, balloon, and baking soda) **Record the mass in the data table** (on page 2)

7. With the balloon **still attached** to the flask, firmly hold where the balloon is attached to the flask and lift the balloon so that the baking soda falls into the flask and combines with the vinegar. Swirl gently.

8. **Record/draw all observations** (starting on page 2)

Name:_______________________________ Date:_______________

Part 2: Mass After the Reaction.

1. Using your scale, **find the mass** of the closed system once the chemical reaction has completed. Be sure to keep balloon attached.

2. Record the info into the data table below.

3. Carefully remove the balloon and let all the gas escape.

4. Place the deflated balloon back onto the Erlenmeyer flask.

5. **Find the mass** again using your scale.

6. Record your info in to the data table below.

7. Calculate the mass of the gas that was released and record it in the processed data table.

Raw Data Table

Mass System Start (g)	Mass System End (g)	Mass System After Released Gas (g)

Processed Data Table

Mass of Released Gas (g)

Name:_______________________________ Date:____________________

Observations and Drawings

Name:____________________________________ **Date:**______________________

Analysis and Results

Look at the chemical equation below:

***$NaHCO_3 + CH_3COOH \rightarrow NaOOCCH_3 + H_20 + CO_2$**

Baking Soda + Vinegar → Sodium acetate + Water + Carbon Dioxide

1. Name the reactants:

2. Name the products:

3. Name the gas produced:

4. Compare the mass of the closed system before and after the reaction. Explain your results.

5. Were any new elements introduced into the closed system?

6. Where did the gas come from? Explain.

7. What evidence did you observe to indicate that a chemical reaction took place?

Name:______________________________________ **Date:**_______________________

8. After the gas was released, what happened to the mass of the system and why?

9. *The **"Law of Conservation of Mass"** states that when matter goes through a physical or chemical change, the amount of matter stays the same before and after the changes occur. In other words, matter cannot be created or destroyed.* ----- Did your results support this statement of the Law of Conservation of Mass? Why/Why not?

Conclusion

Write 2-3 sentences on what you learned in this experiment.

Name:__________________________________ **Date:**_____________________

$$2\ AgNO_3\ _{(aq)} + Cu\ _{(s)} \rightarrow CuNO_{3(aq)} + 2\ Ag\ _{(s)}$$

Use the equation listed above to answer the questions:

1. How many atoms of nitrogen (N) are in the reactants? _______________
2. List the products
   a. ______________________________
   b. ______________________________
3. *Put a square around all of the coefficients.*
4. What do the coefficients tell you? Be specific for this equation.

____

____

____

____

5. *Put a circle around all the subscripts.*
6. What do the subscripts tell you? Be specific for this equation.

____

____

____

____

Name:_____________________________________ **Date:**______________________

7. *Circle all that apply:*

   $AgNO_3$ is a

   a. Compound
   b. Molecule
   c. Element
   d. Chemical Formula
   e. Chemical Reaction
   f. Reactant
   g. Product
   h. Coefficient
   i. Subscript
   j. Atom

8. How many atoms of oxygen (O) are there in the products? _______________

9. What state (solid, liquid, or gas) is silver in as a product? ____________________

10. How does this chemical reaction demonstrate the law of the conservation of mass?

____

____

____

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____

____

____

Activity #6 – FA Chemical Formulas and Conservation of mass

Name:________________________________ **Date:**____________________

Activity #6 - FA Chemical formulas and Conservation of mass

For chemical equation
$2AgI + Na_2S \rightarrow Ag_2S + 2NaI$

What atoms are rearranged to form new products?

For chemical equation
$2AgI + Na_2S \rightarrow Ag_2S + 2NaI$

How many atoms of silver (Ag) are in the products?

For chemical equation
$2AgI + Na_2S \rightarrow Ag_2S + 2NaI$

What are the reactants?

For chemical equation
$2AgI + Na_2S \rightarrow Ag_2S + 2NaI$

How is the Law of Conservation of Mass demonstrated (shown) in this chemical reaction?

Draw a diagram for water (H_2O)

Draw a diagram for the chemical equation

$2AgI + Na_2S \rightarrow Ag_2S + 2NaI$

Name:____________________________________ **Date:**______________________

Activity #6 - FA Chemical formulas and Conservation of mass

What does a chemical formula tell you? Can you give an example of a chemical formula with your answer?

For chemical equation
$2AgI + Na_2S \rightarrow Ag_2S + 2NaI$

List one element

For chemical equation
$2AgI + Na_2S \rightarrow Ag_2S + 2NaI$

List one atom

For chemical equation
$2H_2O \rightarrow 2H_2 + O_2$

List one compound

For chemical equation
$2H_2O \rightarrow 2H_2 + O_2$

List one molecule

If you can not create elements in a chemical reaction, what happens to the atoms to form new products?

How do we get Ag_2S and NaI from AgI and Na_2S?

2

Name:______________________________ **Date:**__________________

Chemistry: Atomic Structure Quiz

Interpretation Unit

1. Write the atomic molecule equation for $\mathbf{2H_2 + O_2 \rightarrow 2H_2O}$

Use this chemical reaction that you did in the lab to answer questions 5 – 10.

$$\mathbf{2\ Mg\ (s) + O_2\ (g) \rightarrow 2\ MgO\ (s)}$$

2. How many magnesium **molecules** are in the reactants? ______________
3. How many oxygen **molecules** are in the reactants? ______________

Name:________________________________ Date:____________________

4. How many oxygen **atoms** are in the reactants? _____________

5. How many oxygen **atoms** are in the products? _____________

6. A student weighs out 10 g of Mg and burned it in a hot Bunsen burner flame. He weighs his MgO and measures 15 g. How many grams of oxygen were involved in this reaction? _____________

7. Describe what is happening to the atoms in the chemical reaction of question 6.

____

____

____

Activity #9 – Clay model

Name:______________________________ **Date:**______________

Learning Goal: 4.36 Be able to describe and illustrate an atom and its parts (nucleus, protons and electrons) using a simple model, e.g. Dalton model

TASK: Build a 3D clay model of the atomic structure of one/two elements of your choice from the first 20 elements. Follow these instructions:

1. Sign-up in this doc[i] by adding your name and the element(s) you have chosen for this activity. NOTE: do not choose an element that has been already chosen by someone else.
2. Build your 3D model using clay and toothpicks. Follow these guidelines: Red = **electrons** Yellow = **neutrons** Green = **protons**
3. If you need help, you can revisit the animation[j] we used in the previous lesson. Pay attention to the atomic structure and location of different subatomic particles!
4. Once the model is finished, place it on a ½ sheet of paper with its atomic symbol (including atomic mass and atomic number). Include a color key for your model.
5. Assess your model using the rubric below, specifying in which state you are for each of the criterion. Hand this document in when you are done.

RUBRIC

Criterion	Mastery	Meets	Developing	Beginning
Subatomic particles	The number of protons, neutrons and electrons is correct. The different particles' size is shown.	The number of protons, neutrons and electrons are correct.	The number of one kind of particles might be wrong.	The number of more than one kind of particles might be wrong.
Structure	The model clearly shows the correct atomic structure with no mistakes.	The model shows the correct atomic structure. Number of electrons in one energy level might be incorrect	The model shows the correct atomic structure). Energy levels are not properly built	The model shows an incorrect atomic structure
Atomic symbol		The atomic symbol is correct and includes atomic mass and atomic number	The atomic symbol is partially correct and includes atomic mass and atomic number. There might be one mistake	The atomic symbol is incorrect or is missing information.
Color key accuracy	The color key includes all particles and is correct. It is easy to read, and clearly identified.	The color key includes all particles and is correct.	The color key is not completely right.	The color key is missing

[i] https://drive.google.com/open?id=1SsGYCwSBQny9kz0Do2C8o8a_xsi8bJgSNRM36L5AbHg

[j] http://www.kscience.co.uk/animations/atom.htm

Activity #9 – Sign up sheet

Name:____ **Date:**____________________

Atomic Structure - Clay model

TASK: choose 1-2 elements (I should have told you how many you will work on) for which you will build a atomic structure clay models.

Student name	Element(s)

Activity #9 – Reflection

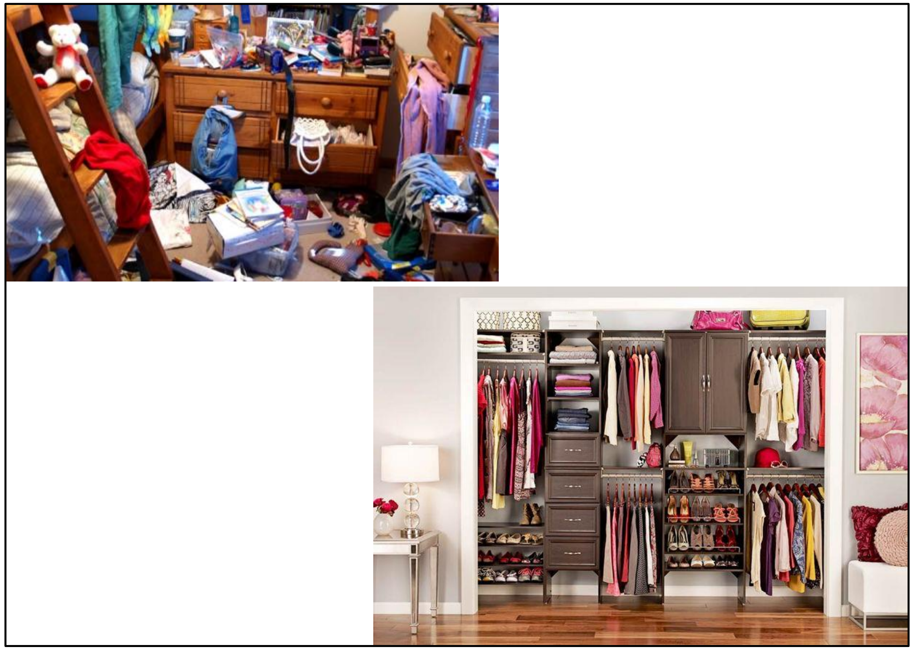
Name:____ **Date:**___________________

Even strongest optical microscopes can only show things up to 2000 times larger than they are, which is nowhere near enough to make out an atom. Electron microscopes work in a different way, by firing beams of electrons that can produce an image magnified up to ten million times the original size. Although an impressive achievement, even this is only just enough to make out the fuzzy shape of an atom. No one has ever been able to see the structure of an atom – scientists can only theorize on what this would look like, based on experiments and their observation of results.

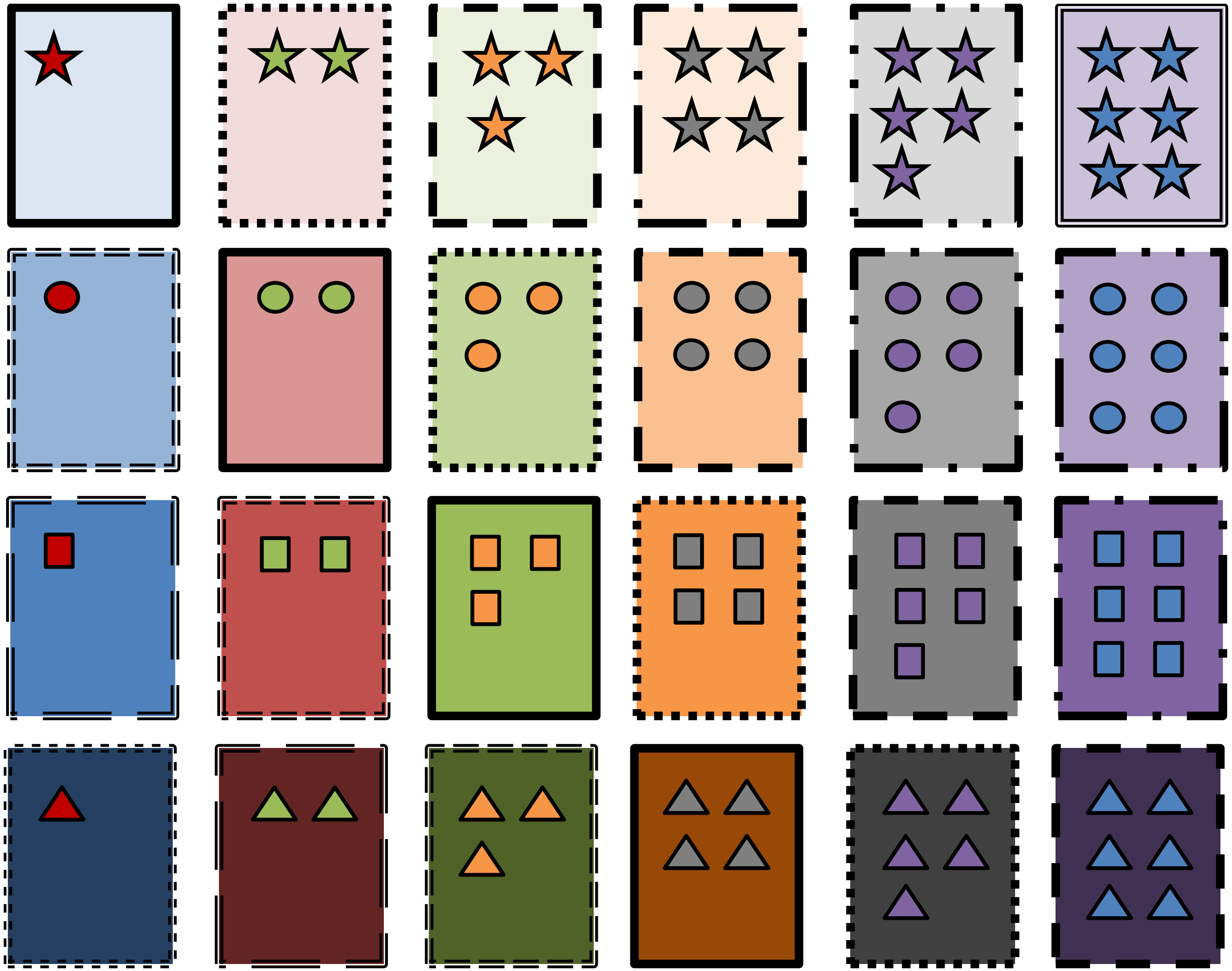
TASK: Answer the following in a Google Docs and share with me:

- How is the model you have made an interpretation?
- In what ways does a diagram help to explain complex ideas?
- In what ways is a diagram different to a photograph?
- Which is more 'true': a diagram or a photograph? Might they be different versions of the same 'truth'?

Activity #10 – PowerPoint



Activity #10 – Periodic Table Cards



Activity #11 – Timeline Exemplar

Name:____ **Date:**______________________________

Activity #11 – History of the atom timeline handout and rubric

Name:____ **Date:**______________________

TASK: Create a timeline that represents the history of the atom. Once you finish the timeline, swap it with a partner and give him feedback on how to improve his timeline using the rubric below. Use the feedback provided by your classmate to make corrections in your own timeline before submitting it to the teacher.

RUBRIC

Criterion	Mastery	Meets	Developing	Beginning
Title and name	Title is "catchy". Both title and name are well positioned and of appropriate size.	The title and name are well positioned in the timeline.	Title is not big enough or name is in the wrong place.	Title is small or too short and the name is wrong or missing.
Layout	Information is perfectly organized and the flow is from left to right to help reading.	Information is in an order that makes sense.	Flow exists but not in the proper order. The information is scattered.	There is no identifiable organization.
Writing	Scientific vocabulary is properly used.	No spelling errors. Correct grammar.	One or two minor spelling or grammatical errors.	Major spelling or grammatical errors
Appearance	Readable from 2m distance. Images are appropriate and enhance the presentation.	Colorful, neat and easy to read. Events are placed in order and There is an image for each event in the timeline.	Few colors. One event is missing an image. Mostly neat.	One color. Not neat and difficult to read. Events are not placed in order. Images don't match the topic or are missing.
Content	The text points out the differences with previous knowledge and emphasizes the significance of the scientific advance.	Includes at least 6 events, labelled and scaled. All events have a short text including the scientific progress, scientist name, one picture and date.	Includes 4-5 events. The order is right but not scaled. One event lacks the scientific progress, scientist name, picture or date.	Includes less than 4 events. Events are not placed in order or lack the text, picture or date.

Name:_________________________________ Date:____________________

Mimicking Rutherford's Gold Foil Experiment

Adapted from Eric Muller - Exploratorium 2003

(http://www.exo.net/~emuller/activities/Rutherford%20Roller.pdf)

You will roll marbles under the cardboard to find out what's under it. The two basic questions to consider are:

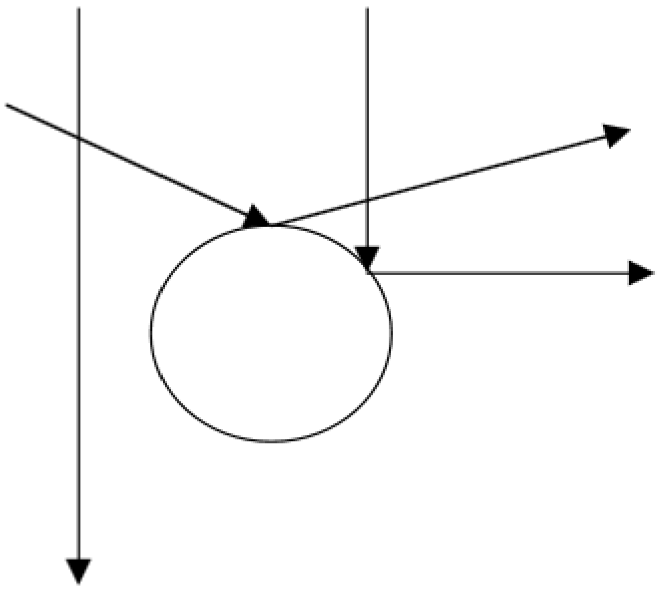
1) What's the shape of the object?

2) Where's the object located?

There are two rules for this activity:

- You may not look under the cardboard until instructed.
- You can only roll marbles under the cardboard to figure out what's there.

Before starting the experiments, you might want to get familiar on how marbles roll and bounce off of other objects. Take objects from the classroom with different shapes, hit them with a marble and check the trajectories of the marble after collision (as in the following picture).



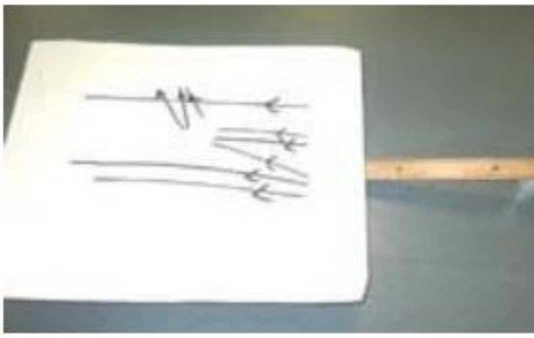
Activity #12 – Rutherford's Experiment

Name:______________________________ **Date:**__________________

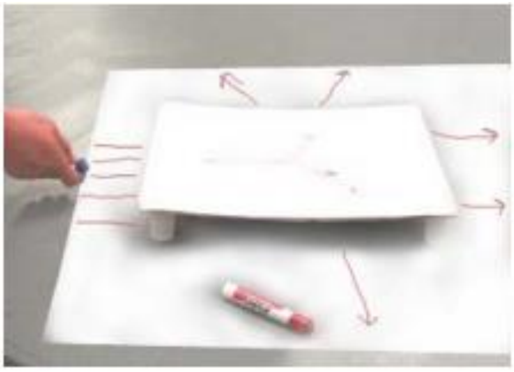
1) *Decide how will you collect your data.* You will draw lines that show where the marble enters its journey under the board and where it exits from under the board. Since you cannot look under the board, the lines represent inferred paths of travel.

There are two techniques to choose from:

a. One method is to place a piece of paper on top of the board and draw the line on this sheet (see drawing to the right).



b. Another method is to place the device on top of a large sheet of paper and draw the lines here (see drawing to the right). When finished, the device can be lifted and the lines can be extended to show where the shape might be located.



2) Once you have decided on the technique you will use to collect the data, you may begin.

3) Once you have collected enough data, make a prediction by creating a drawing of the shape and location of your item.

4) Your teacher will then reveal the shape to you.

5) Answer the questions on the next page.

Name:__________________________________ Date:_____________________

Questions from Rutherford Lab

1. What was the challenge in this lab?

2. Did you and your lab partners interpret the data the same way or differently? Explain.

3. How did the ideas of your lab partners influence your ideas?

4. What is a "theory"?

5. In science, very few theories are thought to be true by all people. Why is this?

6. Why do scientists sometimes interpret discoveries in different ways?

7. How is this lab similar to the gold-foil experiment that Rutherford performed?

Name:______________________________ Date:__________________

Periodic Trends: Straw Lab

Objective: To create a visual representation of periodic trends as related to the following physical and chemical properties: atomic size, ionization energy and electronegativity.

Atomic Radius: the size of an atom measured in either nanometers (nm) or angstroms (Å).

Ionization Energy: the energy needed to remove an electron from an atom measured in kilojoules per mole (kj/mol) of an atom.

Electronegativity: the relative ability of an atom to attract electrons towards itself.

Materials: For this lab you will need a sheet with 3 small periodic tables, straws, scissors, a metric ruler, your notebook and access to a hot glue gun.

Procedure:

1) Complete the data table for each trend. Each person should have their own data tables!

2) For each trend, calculate the scale factor according to the instructions. Using the scale factor, measure the straw and cut it to the appropriate size.

3) You will then use the glue gun to glue the straw to the periodic table in the box that represents the element's location on the periodic table.

4) Answer the questions for each trend in a Google Shared document that you share with me. Everyone will create his/her own document! ***Title the document "Periodic Trends".***

Activity #13 – Periodic Trends: Straw Lab

Name:_________________________________ Date:____________________

Atomic Radius:

The radius of the following atoms has been estimated to have the following values:

Name	Symbol	Atomic Number	Size of Radius (nm)	Calculated Straw Length (cm)
Fluorine			**0.064**	
Chlorine			**0.0999**	
Bromine			**0.114**	
Iodine			**0.1133**	
Sodium			**0.186**	
Magnesium			**0.160**	
Aluminum			**0.143**	
Silicon			**0.117**	
Phosphorus			**0.110**	
Sulfur			**0.104**	

To calculate the scale factor:

Measure the length of a precut straw = __________ cm

Divide the length of the straw by 2 = ___________cm

Divide that number by 0.186 = **Scale factor____________ cm**

To calculate the length of your straw:

Multiply the scale factor by the size of radius given in your data table.

Activity #13 – Periodic Trends: Straw Lab

Name:______________________________________ Date:_______________________

Answer the following questions in your lab notebook:

1) In a sentence, describe the relationship between atomic number and the size of the atom's radius going down a group on the periodic table.

2) Why does this relationship make sense in relation to what you know about elements on the periodic table?

3) In a sentence, describe the relationship between atomic number and the size of each atom's radius when going across a period on the periodic table.

4) Why does this trend make sense in relation to what you know about the attraction between subatomic particles within the atom?

Activity #13 – Periodic Trends: Straw Lab

Name:___________________________________ **Date:**_____________________

Ionization Energy:

The ionization energy for the following elements is estimated to have the following values:

Name	Symbol	Atomic Number	Ionization Energy (kj/mol)	Calculated Straw Length (cm)
Beryllium			900	
Magnesium			736	
Calcium			590	
Lithium			519	
Boron			799	
Carbon			1088	
Nitrogen			1406	
Oxygen			1314	
Fluorine			1682	
Neon			2080	

To calculate the scale factor:

Measure the length of a precut straw = __________ cm

Divide the length of the straw by 2 = ____________cm

Divide that number by 2080 = **Scale factor_____________ cm**

To calculate the length of your straw:

Multiply the scale factor by the ionization energy given in your data table.

Activity #13 – Periodic Trends: Straw Lab

Name:____________________________________ Date:______________________

Answer the following questions in your notebook:

1) In a sentence, describe the relationship between atomic number and the amount of ionization energy as you go down a group on the periodic table.

2) Based on your understanding of ionization energy and atomic size, explain why this trend makes sense as you go down a group on the periodic table.

3) In a sentence, describe the relationship between atomic number the amount of ionization energy as you go across a period on the periodic table.

4) Based on your understanding of ionization energy and valence electrons, explain why this trend makes sense as you move across the periodic table.

Activity #13 – Periodic Trends: Straw Lab

Name:____________________________________ **Date:**______________________

Electronegativity:

The electronegativity for the following elements is estimated to have the following values:

Name	Symbol	Atomic Number	Electronegativity	Calculated Straw Length (cm)
Nitrogen			3.0	
Phosphorus			2.1	
Arsenic			2.0	
Antimony			1.9	
Bismuth			1.9	
Lithium			1.0	
Beryllium			1.5	
Boron			2.0	
Carbon			2.5	
Oxygen			3.5	
Fluorine			4.0	

To calculate the scale factor:

Measure the length of a precut straw = ___________ cm

Divide the length of the straw by 2 = _____________cm

Divide that number by 4.0 = **Scale factor______________ cm**

To calculate the length of your straw:

Multiply the scale factor by the electronegativity value given in your data table.

Activity #13 – Periodic Trends: Straw Lab

Name:____________________________________ Date:______________________

Answer the following questions in your lab notebook:

1) In a sentence, describe the relationship between atomic number and the amount of electronegativity as you go down a group on the periodic table.

2) Based on your understanding of electronegativity and atomic size, explain why this trend makes sense as you go down a group on the periodic table.

3) In a sentence, describe the relationship between atomic number the amount of electronegativity as you go across a period on the periodic table.

4) Based on your understanding of electronegativity and valence electrons, explain why this trend makes sense as you move across the periodic table.

Name:___________________________________ Date:_____________________

Chemistry: Atomic Structure Quiz

Interpretation Unit

1. _______The Plum Pudding model of the atom included which of the following:

   a. A nucleus containing protons and neutrons with electrons circling the outside of the nucleus
   b. A nucleus containing protons and neutrons evenly distributed throughout the atom
   c. Electrons scattered evenly throughout a positively charged atom
   d. A nucleus containing electrons with protons circling the outside of the nucleus

2. _____ The current model of the atom includes which of the following:

   a. A nucleus containing protons and neutrons with electrons circling the outside of the nucleus
   b. A nucleus containing protons and neutrons evenly distributed throughout the atom
   c. Electrons scattered evenly throughout a positively charged atom
   d. A nucleus containing electrons with protons circling the outside of the nucleus

3. _____ The current model of the atom is developed after the gold-foil experiment performed by

   a. Rutherford
   b. Thompson
   c. Edison
   d. Dalton

4. _____ Who first proposed the existence of atoms?

   a. Dalton
   b. Thomson
   c. Democritus
   d. Rutherford

5. _____ Niels Borh proposed

   a. The existence of electrons
   b. That electrons are negatively charged
   c. That electrons are not in the nucleus
   d. That electrons exist in specific energy levels

Activity #14 – Atomic Structure Quiz

Name:________________________________ **Date:**____________________

Use this chemical reaction to answer questions 6 – 13.

$$2\ Mg_{(s)} + O_{2(g)} \rightarrow 2\ MgO_{(s)}$$

magnesium + oxygen → magnesium oxide

6. How many magnesium **atoms** react with oxygen in this reaction? _____________
7. How many oxygen **molecules** are in the reactants? _____________
8. How many oxygen **atoms** are in the reactants? _____________
9. How many oxygen **atoms** are in the products? _____________
10. Which of the reactants or products is a **compound**? _____________
11. Which of the reactants or products is a **gas**? _______________
12. A student weighs out 10 g of magnesium and burns it in a hot Bunsen burner flame. He weighs his MgO and measures 15 g. How many grams of oxygen were involved in this reaction? _____________
    a. Explain your answer to #12:

    ____

    ____

    ____

    ____

13. Describe what is happening to the atoms in this chemical reaction.

    ____

    ____

    ____

Activity #14 – Atomic Structure Quiz

Name:___________________________________ **Date:**_____________________

14. Is the atomic model an interpretation or a fact? Explain

____

____

____

15. _____ What is atomic radius?

    a. The relative ability of an atom to attract electrons to itself
    b. The energy needed to remove an electron from an atom
    c. The size of an atom

16. _____ What is electronegativity?

    a. The relative ability of an atom to attract electrons to itself
    b. The energy needed to remove an electron from an atom
    c. The size of an atom

17. _____ What is ionization energy?
    a. The relative ability of an atom to attract electrons to itself
    b. The energy needed to remove an electron from an atom
    c. The size of an atom

Use the periodic table to answer questions 18 – 23.

18. Which element is bigger, Li or Cs? ________

19. Which element is less likely to lose an electron, Al or Cl? ___________

20. Which element is less likely to gain an electron, F or O? _________

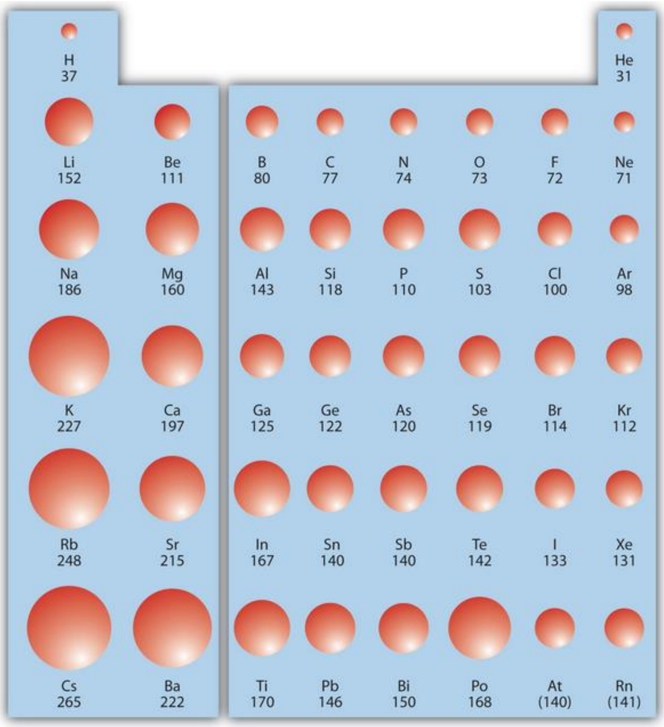
21. Which element is smaller, Na or S? _________

22. Which element is more likely to lose an electron, Be or Ba? _________

23. Which element is more likely to gain an electron, N or As? _________

Activity #14 – Atomic Structure Quiz

Name:____________________________________ **Date:**______________________



24. What trend is represented by the diagram above? Explain your answer.

Activity #14 – Atomic Structure Quiz - Answers

Name:____________________________________ Date:______________________

8. **C** The Plum Pudding model of the atom included which of the following:

    a. A nucleus containing protons and neutrons with electrons circling the outside of the nucleus
    b. A nucleus containing protons and neutrons evenly distributed throughout the atom
    c. Electrons scattered evenly throughout a positively charged atom
    d. A nucleus containing electrons with protons circling the outside of the nucleus

9. **A** The current model of the atom includes which of the following:

    a. A nucleus containing protons and neutrons with electrons circling the outside of the nucleus
    b. A nucleus containing protons and neutrons evenly distributed throughout the atom
    c. Electrons scattered evenly throughout a positively charged atom
    d. A nucleus containing electrons with protons circling the outside of the nucleus

10. **A** The current model of the atom is developed after the gold-foil experiment performed by

    a. Rutherford
    b. Thompson
    c. Edison
    d. Dalton

11. **C** Who first proposed the existence of atoms?

    a. Dalton
    b. Thomson
    c. Democritus
    d. Rutherford

12. **D** Niels Borh proposed

    a. The existence of electrons
    b. That electrons are negatively charged
    c. That electrons are not in the nucleus
    d. That electrons exist in specific energy levels

Activity #14 – Atomic Structure Quiz - Answers

Name:______________________________________ **Date:**_______________________

Use this chemical reaction to answer questions 6 – 13.

$$2\ Mg_{(s)} + O_{2(g)} \rightarrow 2\ MgO_{(s)}$$

magnesium + oxygen → magnesium oxide

13. How many magnesium **atoms** react with oxygen in this reaction? **2**
14. How many oxygen **molecules** are in the reactants? **1**
15. How many oxygen **atoms** are in the reactants? **2**
16. How many oxygen **atoms** are in the products? **2**
17. Which of the reactants or products is a **compound**? **MgO and O_2**
18. Which of the reactants or products is a **gas**? **O_2 (oxygen)**
19. A student weighs out 10 g of magnesium and burns it in a hot Bunsen burner flame. He weighs his MgO and measures 15 g. How many grams of oxygen were involved in this reaction? **5**
    a. Explain your answer to #12:

    Law of Conservation of Mass

    The products weigh a total of 15 grams therefore the reactants must also weigh 15 grams. Thus 15 g – 10 g (the weight of the Mg) = 5 g (the weight of the oxygen).

20. Describe what is happening to the atoms in this chemical reaction.

    Atoms are being rearranged.

Activity #14 – Atomic Structure Quiz - Answers

Name:____________________________________ Date:______________________

21. Is the atomic model an interpretation or a fact? Explain

    It is interpretation of many experiments performed by many scientists. We can not see the atom so it is a theory and an interpretation.

22. **C** What is atomic radius?

    a. The relative ability of an atom to attract electrons to itself
    b. The energy needed to remove an electron from an atom
    c. The size of an atom

23. **A** What is electronegativity?

    a. The relative ability of an atom to attract electrons to itself
    b. The energy needed to remove an electron from an atom
    c. The size of an atom

24. **B** What is ionization energy?
    a. The relative ability of an atom to attract electrons to itself
    b. The energy needed to remove an electron from an atom
    c. The size of an atom

Use the periodic table to answer questions 18 – 23.

25. Which element is bigger, Li or Cs? **Cs**

26. Which element is less likely to lose an electron, Al or Cl? **Cl**

27. Which element is less likely to gain an electron, F or O? **O**

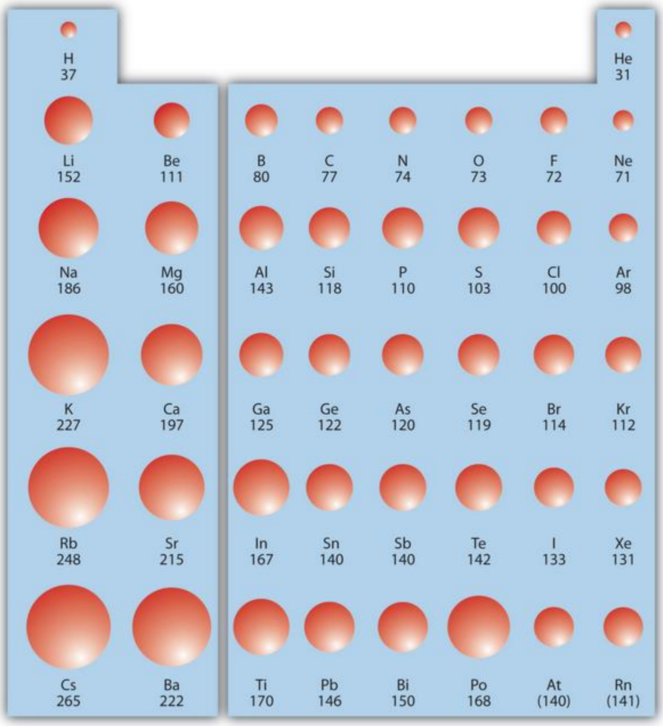
28. Which element is smaller, Na or S? **S**

29. Which element is more likely to lose an electron, Be or Ba? **Ba**

30. Which element is more likely to gain an electron, N or As? **N**

Activity #14 – Atomic Structure Quiz - Answers

Name:____ **Date:**_________________________



31. What trend is represented by the diagram above? Explain your answer

Atomic Radius. It matches the trend of decreasing going from left to right across a period. It also matches the trend of increasing size going down a column.

Test Rubric

Name:______________________________ **Date:**__________________

Label	Descriptor
Exemplary	• Accomplishes the purpose of the task correctly and **shows an application with insightful inferences** • Recorded work includes appropriate scientific vocabulary and conventions (notations, structures, labeled diagrams, etc). • Answers show evidence of **application, analysis, and evaluation** of relevant scientific concepts, principles or theories (big ideas). • **Demonstrates an awareness of the nature of science (scientific reasoning, writing and methodology, limitations of science)**
Meets/ exemplary	• Accomplishes the purpose of the task correctly and **shows an application** • Recorded work includes appropriate scientific vocabulary and conventions (notations, structures, labeled diagrams, etc). • Answers show evidence of **application and analysis** of relevant scientific concepts, principles or theories (big ideas).
Meets	• Accomplishes the purpose of the task correctly • Recorded work includes appropriate scientific vocabulary and conventions (notations, structures, labeled diagrams, etc). • Answers show evidence of **understanding** of relevant scientific concepts, principles or theories (big ideas).
Approaching/ meets	• **Almost** accomplishes the purpose of the task correctly • Recorded work includes appropriate scientific vocabulary and conventions (notations, structures, labeled diagrams, etc). • Answers show evidence of **partial understanding** of relevant scientific concepts, principles or theories (big ideas).
Approaching (credit awarded)	• **Partially** accomplishes the purpose of the task correctly • Recorded work includes **some** appropriate scientific vocabulary and conventions (notations, structures, labeled diagrams, etc). • Answers show evidence of **partial understanding** of relevant scientific concepts, principles or theories (big ideas).
Beginning	• Partially accomplishes the purpose of the task correctly **(some key elements are missing or incorrect)** • Recorded work includes **some** appropriate scientific vocabulary and conventions (notations, structures, labeled diagrams, etc). • Answers show evidence of **some understanding** of relevant scientific concepts, principles or theories (big ideas) **but the scientific reasoning is lacking**
Does not meet	• **The student is unable to answer or the answers are meaningless or incorrect**