AI and Chemistry for Middle School

1. Topics covered

1.1 Periodic Table

This topic is probably the one of the most important topic of Chemistry in middle school. It introduces the concept of atoms and element. It also explains different properties of elements such as atomic number, atomic mass, number of protons, number of electrons, and number of neutrons. Future chapters like energy levels, covalent bond and ionic bond are all based on this concept.

ASP provides a way to model the problem. The number of protons and atomic mass can be entered as facts and can be used to find number of electrons, atomic number and neutrons. The elements can be grouped according to the number of valence electrons.

1.2 Chemical Reaction

This topic introduces the concept of reactants and products in chemical reaction. It talks about how same atoms that are present in reactant are present in products. This topic is important because students are taught about how atoms and molecules of different substance react together to form product. It is also interesting to see how different combination of reactant produce different products.

ASP can be used to model chemical reaction and check if a chemical reaction is balanced or not. First, the reactant and product in a reaction is labelled and added as knowledge. After that the number of molecules of reactant and product are added as knowledge. The the information about number atoms in each substance is added and this knowledge along with above mentioned knowledge is used to check if a reaction is balanced.

1.3 Density: Sink and Float of Solids and Liquids

This topic talks about density and explains why some solids sink in a liquid and other float. It also talks about why some liquid sink in another liquid and others do not. This topic gives interesting examples to demonstrate the students how difference in density causes object to float and sink.

Density is calculated by dividing mass of a substance with its volume. Mass and volume of a substance can be entered as knowledge and we can write a rule to calculate its density. Then density of different substance can be checked to see which one is more dense. An object floats on another if its density is less or sinks otherwise.

2. TEKS standards on the topics

2.1 Standards for Periodic Table

By the item (b).(5).c of TEKS §112.20. Science, Grade 8, Beginning with School Year 2010-2011. (http://ritter.tea.state.tx.us/rules/tac/chapter112/ch112b.html), the student is expected to
"interpret the arrangement of the Periodic Table, including groups and periods, to explain how properties are used to classify elements;"

2.2 Standards for Chemical Reaction

By the item (b).(5).f of TEKS §112.20. Science, Grade 8, Beginning with School Year 2010-2011. (http://ritter.tea.state.tx.us/rules/tac/chapter112/ch112b.html), the student is expected to "recognize whether a chemical equation containing coefficients is balanced or not"

2.3 Standards for Density

By the item (b).(6).f of TEKS §112.18. Science, Grade 6, Beginning with School Year 2010-2011. (http://ritter.tea.state.tx.us/rules/tac/chapter112/ch112b.html), the student is expected to "calculate density to identify an unknown substance"

3. Contents of Topic

3.1 Periodic Table

Following are the key content of the topic:

- The periodic table is a chart containing information about the atoms that make up all matter.
- An element is a substance made up of only one type of atom.
- The atomic number of an atom is equal to the number of protons in its nucleus.
- The number of electrons surrounding the nucleus of an atom is equal to the number of protons in its nucleus.
- Different atoms of the same element can have a different number of neutrons.
- Atoms of the same element with different numbers of neutrons are called "isotopes" of that element.
- The atomic mass of an element is the average mass of the different isotopes of the element.

- The atoms in the periodic table are arranged to show characteristics and relationships between atoms and groups of atoms.

(http://www.middleschoolchemistry.com/lessonplans/chapter4/lesson2)

Students are taught about this topic by making them study the periodic table in detail. They will be introduced to the basic informations, name, symbol, atomic number, and atomic mass, of the first twenty elements. They are given 20 flashcards with properties of an element and they have to match it with its name.

Students will identify different atoms by the number of protons in the nucleus and realize that the number of electrons equals the number of protons in a neutral atom. They will also be able to explain the meaning of atomic number and atomic mass.

3.2 Chemical Reaction

This topic introduces following concept:

- A physical change, such as a state change or dissolving, does not create a new substance, but a chemical change does.
- In a chemical reaction, the atoms and molecules that interact with each other are called reactants.
- In a chemical reaction, the atoms and molecules produced by the reaction are called products.
- In a chemical reaction, only the atoms present in the reactants can end up in the products. No new atoms are created, and no atoms are destroyed.
- In a chemical reaction, reactants contact each other, bonds between atoms in the reactants are broken, and atoms rearrange and form new bonds to make the products.

.(http://www.middleschoolchemistry.com/lessonplans/chapter6/lesson1)

One of the reaction mentioned under this topic is the reaction where hydrogen peroxide decomposes into water and oxygen. Hydrogen Peroxide is not very stable and slowly decomposes into water and oxygen. But when yeast is added as catalyst, the reaction speeds up.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

Another reaction mentioned in this topic is the reaction where carbon dioxide is mixed with water to form carbonic acid.

$$H_2O + CO_2 \text{ -> } H_2CO_3$$

Student are taught about these reactions by carrying out these reactions in the lab.

3.3 Density: Sink and Float of Solids and Liquids

Following are the main concepts of this topic:

- The density of an object determines whether it will float or sink in another substance.
- An object will float if it is less dense than the liquid it is placed in.
- An object will sink if it is more dense than the liquid it is placed in
- Since density is a characteristic property of a substance, each liquid has its own characteristic density.
- The density of a liquid determines whether it will float on or sink in another liquid.
- A liquid will float if it is less dense than the liquid it is placed in.
- A liquid will sink if it is more dense than the liquid it is placed in.

(http://www.middleschoolchemistry.com/lessonplans/chapter3/lesson5)

This topic is also taught by demonstrating it in the lab. Students measure mass of wax, clay and water for equal volume of water. Similarly mass of oil and alcohol is measured for equal volume of water. The object with density greater than water sinks while object with density less than water floats on water.

4. Problem descriptions, models and SPARC programs for each topic

4.1 Periodic Table

Problem description

Background knowledge: Periodic table consists of first 20 elements. Each element is associated with symbol, atomic mass and number of protons. Number of protons is equal to the number of electrons or atomic number. The elements are classified into groups from 1 to 8. Elements of same group have same number of valence electrons except hydrogen and helium.

Questions and intended answers:

- What is the number of electrons in an helium? 2
  What is atomic number of hydrogen? 1
- What is the symbol of hydrogen? h
  What group does helium belong? gorup2
- What's the number of neutrons in helium? 2

Modeling

Objects: hydrogen, helium, lithium, beryllium, boron, carbon, nitrogen, oxygen, fluorine, neon, sodium, magnesium, aluminium, silicon, phosphorus, sulphur, chlorine, argon, potassium, calcium, h,he, li, be, b, c, n, o, f, ne, na, mg, al, si, p, s, cl, ar, k, ca

Relations:

symbolOf (E, S) denotes that S is the symbol of E.
protonOf (E,S) denotes that S is the number of proton in E.
neutronOf (E,S) denotes that S is the number of neutron in E.
atomicNum (E,S) denotes that S is the atomic number of E.
electronOf (E,S) denotes that S is the number of electron in E.
atomicMass (E,S) denotes that S is the atomic mass of E.
group1(E) denotes that E belongs to group 1.
group2(E) denotes that E belongs to group 2.
group3(E) denotes that E belongs to group 3.
group4(E) denotes that E belongs to group 4.
group5(E) denotes that E belongs to group 5.
group6(E) denotes that E belongs to group 6.
group7(E) denotes that E belongs to group 7.
group8(E) denotes that E belongs to group 8.
ve(E, S) denotes that number of valence electrons in E is S.

Knowledge and Rules:

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%Symbols
% h is the symbol of hydrogen.
symbolOf(hydrogen, h).
 % he is the symbol of helium.
symbolOf(heluim, he).
 % li is the symbol of lithium.
symbolOf(lithium, li).
 % be is the symbol of beryllium.
symbolOf(berylium, be).
 % b is the symbol of boron.
symbolOf(boron, b).
 % c is the symbol of carbon.
symbolOf(carbon, c).
 % n is the symbol of nitrogen.
symbolOf(nitrogen, n).
 % o is the symbol of oxygen.
symbolOf(oxygen, o).
 % f is the symbol of fluorine.
symbolOf(fluorine, f).
 % ne is the symbol of neon.
symbolOf(neon, ne).
 % na is the symbol of sodium.
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symbolOf(sodium, na).
 % mg is the symbol of magnesium.
symbolOf(magnesium, mg).
 % al is the symbol of aluminium.
symbolOf(aluminium, al).
 % si is the symbol of silicon.
symbolOf(silicon, si).
 % p is the symbol of phosphorous.
symbolOf(phosphorous, p).
 % s is the symbol of sulphur.
symbolOf(sulphur, s).
 % cl is the symbol of chlorine.
symbolOf(chlorine, cl).
 % ar is the symbol of argon.
symbolOf(argon, ar).
 % k is the symbol of potassium.
symbolOf(potassium, k).
 % ca is the symbol of calcium.
symbolOf(calcium, ca).

% Protons
 % Number of proton in hydrogen is 1.
protonOf(h, 1).
 % Number of proton in helium is 2.
protonOf(he, 2).
 % Number of proton in lithium is 3.
protonOf(li, 3).
 % Number of proton in beryllium is 4.
protonOf(be, 4).
 % Number of proton in boron is 5.
protonOf(b, 5).
 % Number of proton in carbon is 6.
protonOf(c, 6).
 % Number of proton in nitrogen is 7.
protonOf(n, 7).
 % Number of proton in oxygen is 8.
protonOf(o, 8).
 % Number of proton in fluorine is 9.
protonOf(f, 9).
 % Number of proton in neon is 10.
protonOf(ne, 10).
 % Number of proton in sodium is 11.
protonOf(na, 11).
 % Number of proton in magnesium is 12.
protonOf(mg, 12).
 % Number of proton in aluminium is 13.
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protonOf(al, 13).
 % Number of proton in silicon is 14.
protonOf(si, 14).
 % Number of proton in phosphorous is 15.
protonOf(p, 15).
 % Number of proton in sulphur is 16.
protonOf(s, 16).
 % Number of proton in chlorine is 17.
protonOf(cl, 17).
 % Number of proton in argon is 18.
protonOf(ar, 18).
 % Number of proton in potassium is 19.
protonOf(k, 19).
 % Number of proton in calcium is 20.
protonOf(ca, 20).


%Atomic Mass
 % Atomic mass of hydrogen is 0.
atomicMass(h, 1).
% Atomic mass of helium is 4.
atomicMass(he, 4).
% Atomic mass of lithium is 7.
atomicMass(li, 7).
% Atomic mass of beryllium is 9.
atomicMass(be, 9).
% Atomic mass of boron is 11.
atomicMass(b, 11).
% Atomic mass of carbon is 12.
atomicMass(c, 12).
% Atomic mass of nitrogen is 14.
atomicMass(n, 14).
% Atomic mass of oxygen is 16.
atomicMass(o, 16).
% Atomic mass of fluorine is 19.
atomicMass(f, 19).
% Atomic mass of neon is 20.
atomicMass(ne, 20).
% Atomic mass of sodium is 23.
atomicMass(na, 23).
% Atomic mass of magnesium is 24.
atomicMass(mg, 24).
% Atomic mass of aluminium is 27.
atomicMass(al, 27).
% Atomic mass of silicon is 28.
atomicMass(si, 28).
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% Atomic mass of phosphorus is 31.
atomicMass(p, 31).
% Atomic mass of sulphur is 32.
atomicMass(s, 32).
% Atomic mass of chlorine is 35.
atomicMass(cl, 35).
% Atomic mass of argon is 40.
atomicMass(ar, 40).
% Atomic mass of potassium is 30.
atomicMass(k, 30).
% Atomic mass of calcium is 40.
atomicMass(ca, 40).

%group
%lithium belongs to group1.
group1(li).
%sodium belongs to group1.
group1(na).
%potassium belongs to group1.
group1(k).
%beryllium belongs to group2.
group2(be).
%magnesium belongs to group2.
group2(mg).
%calcium belongs to group2.
group2(ca).
%boron belongs to group3.
group3(b).
%aluminium belongs to group3.
group3(al).
%carbon belongs to group4.
group4(c).
%silicon belongs to group4.
group4(si).
%nitrogen belongs to group5.
group5(n).
%phosphorous belongs to group5.
group5(p).
%oxygen belongs to group6.
group6(o).
%sulphur belongs to group6.
group6(s).
%fluorine belongs to group7.
group7(f).
%chlorine belongs to group7.
group7(cl).
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%helium belongs to group8.
group8(he).
%neon belongs to group8.
group8(ne).
%argon belongs to group8.
group8(ar).

% atomic number of X element is Y if Y is the proton number of 'X' element.
atomicNum(X,Y) :-protonOf(X,Y).

% number of electron of X element is Y if Y is the proton number of 'X'
element.
electronOf(X,Y):-protonOf(X,Y).

% Number of neutron in X element is Y if atomic number of X element S is
% subtracted from atomic mass of X element Z.
neutronOf(X,Y):- atomicMass(X,S),atomicNum(X,Z), Y=S-Z.

%X has valence electron 1 if it belongs to group1.
ve(X,Y):-group1(X),Y=1.
%X has valence electron 2 if it belongs to group2.
ve(X,Y):-group2(X),Y=2.
%X has valence electron 3 if it belongs to group3.
ve(X,Y):-group3(X),Y=3.
%X has valence electron 4 if it belongs to group4.
ve(X,Y):-group4(X),Y=4.
%X has valence electron 5 if it belongs to group5.
ve(X,Y):-group5(X),Y=5.
%X has valence electron 6 if it belongs to group6.
ve(X,Y):-group6(X),Y=6.
%X has valence electron 7 if it belongs to group7.
ve(X,Y):-group7(X),Y=7.
%X has valence electron 8 or 0 if it belongs to group8.
ve(X,Y):-group8(X),Y=8.
```

4.2 Chemical Reactions

Problem description

Background Knowledge

Hydrogen Peroxide decomposes to form two products, oxygen and water. A molecule of hydrogen peroxide consists two atoms of hydrogen and two atoms of oxygen. A molecule of water consists two atoms of hydrogen and one atom of oxygen and an element of oxygen consists two atoms of oxygen.

Rxn_1: $2H_2O_2 \rightarrow 2H_2O + O_2$

Carbon dioxide reacts with water to produce carbonic acid. Water has two atoms of hydrogen and one atom of oxygen, carbon dioxide has one atom of carbon and two atoms of oxygen and carbonic acid contains two atoms of hydrogen, one atom of carbon and three atoms of oxygen.

Rxn_2: $H_2O + CO_2 \rightarrow H_2CO_3$

A Chemical reaction is balanced if the number of atoms of each element in the reactant side is equal to its number of atoms in the product side.

Questions and intended answers:

1. What are the products of hydrogen peroxide in reaction 1?
   Intended Answer: h2o, o2
2. What is the number of molecule of h2o and o2 ?
   Intended Answer: 2,1.
3. What is total number of atoms of hydrogen and oxygen in reactant?
   Intended Answer: 4,4
4. What is total number of atoms of hydrogen and oxygen in product?
   Intended Answer: 4,4
5. Is reaction 1 balanced?
   Intended Answer: Yes.

Modeling

Objects: h,c,k,o,cl,1..20,rxn_1,rxn_2,h2o2,kclo3,h2o,o2,kcl,co2,h2co3.

Relations:

has_reactant(R,B) denotes reaction R has reactant B.

has_product(R,B) denotes reaction R has product B.

has_atom(S,N,A) denotes substance S has N number of A atoms.

num_molecule(R,N,S) denotes reaction R has N number of substance S.

is_balanced(R) denotes reaction R is balanced.

atoms_in_substance_r(R,S,E,N) denotes R has N number of E atoms in a reactant S of reaction R.

atoms_in__substance_p(R,S,E,N) denotes N is the number of E atoms in a product S of reaction R.

totalR(R,A,N) denotes that the number of atom A in the reactants of R is N.

totalP(R,A,N) denotes that the number of atom A in the products of R is N.

Knowledge/Rules

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% rexn_1= 2h2o2 ->2h2o + o2


%Reaction_1 has reactant h2o2.
        has_reactant(rxn_1,h2o2).

%Reaction_1 has product h2o.
        has_product(rxn_1,h2o).

%Reaction_1 has product o2.
        has_product(rxn_1,o2).

%Substance h2o2 has 2 atoms of hydrogen.
        has_atom(h2o2,2,h).
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%Substance h2o2 has 2 atoms of oxygen.
   has_atom(h2o2,2,o).

%Substance h2o has 2 atoms of hydrogen.
        has_atom(h2o,2,h).

%Substance h2o has 1 atom of oxygen.
        has_atom(h2o,1,o).

%Product o2 has 2 atoms of oxygen.
        has_atom(o2,2,o).

%Reaction_1 has 2 number of h2o2 molecule.
        num_molecule(rxn_1,2,h2o2).

%Reaction_1 has 2 number of h2o molecule.
        num_molecule(rxn_1,2,h2o).

%Reaction_1 has 1 number of o2.
        num_molecule(rxn_1,1,o2).


        % rexn_2= h2o + co2 ->h2co3

%Reaction_2 has reactant h2o.
        has_reactant(rxn_2,h2o).

%Reaction_2 has reactant co2.
        has_reactant(rxn_2,co2).

%Reaction_2 has product h2co3.
        has_product(rxn_2,h2co3).

%Substance h2co3 has 2 atoms of hydrogen..
        has_atom(h2co3,2,h).

%Substance h2co3 has 1 atoms of carbon.
   has_atom(h2co3,1,c).

%Substance h2co3 has 3 atoms of oxygen.
        has_atom(h2co3,3,o).

%Substance co2 has 1 atom of carbon.
        has_atom(co2,1,c).
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%Substance co2 has 2 atom of oxygen.
        has_atom(co2,2,o).


%Product o2 has 2 atoms of oxygen.
        has_atom(o2,2,o).

%Reaction_2 has 1 number of h2o molecule.
        num_molecule(rxn_2,1,h2o).

%Reaction_2 has 1 number of o2.
        num_molecule(rxn_2,1,co2).

%Reaction_2 has 1 number of product h2co3.
        num_molecule(rxn_2,1,h2co3).


% N is total number of E atom of reactant S belonging to reaction R if R has reactant S and
number of molecules of reactant S is M and S has
% O number of E atoms where total number of atom N =M*O.

        atoms_in_substance_r(R,S,E,N):-has_reactant(R,S),num_molecule(R,M,S),
        has_atom(S,O,E),N=M*O.


% N is total number of E atom of product S belonging to reaction R if R has product S and
number of molecules of product S is M, and S has O number of E atoms where total number
of atom N =M*O.

        atoms_in_substance_p(R,S,E,N):-has_product(R,S),num_molecule(R,M,S),
        has_atom(S,O,E),N=M*O.


 % Reaction R is balanced if there is no reason to believe it is not balanced.
        is_balanced(R) :- not -is_balanced(R).
% Reaction R is not balanced if for each atom, the total number of this atom in
 reactant is the not equal to that in the products.

        -is_balanced(R):-totalR(R,A,N), totalP(R,A,M), N!=M.
%Total number of atoms A in reaction R is N if for all NA,S, the sum of atoms in reactant is
N.
         totalR(R,A,N):- #sum{NA,S: atoms_in_substance_r(R,S,A,NA)}=N.


%Total number of atoms A in reaction R is N if for all NA,S, the sum of atoms in product is N.
   totalP(R,A,N):- #sum{NA,S: atoms_in_substance_p(R,S,A,NA)}=N.
```

4.3 Density : Sink and float for solid and liquid

Problem Description:

- *Background knowledge:*

Density of a substance can be found by dividing its mass by its volume. For same volume, mass of water is greater than the mass of wax,oil and alcohol, and mass of water is less than mass of clay. A substance floats in liquid if its density is less than that of liquid and sinks if its density is greater than the liquid.

Mass of water = 80 g
Mass of clay = 90g
Mass of wax = 70g
Mass of oil = 60g
Mass of alcohol= 50g
Volume of water = volume of clay = volume wax = volume of oil = volume of alcohol = 10 cm^3

- *Questions and Intended Answer:*
  - ❖ Is the volume of clay, water and wax same ? Yes
  - ❖ Which is more dense between water and wax ?water
  - ❖ Which is more dense between water and clay ?clay
  - ❖ Does wax float in water? Yes.
  - ❖ Does clay sink in water? Yes

Model:

- *Object:*

  Clay, wax, water, alcohol, oil 1...1000

- Relation:

  mass_Of(X,Y) denotes Y is the mass of substance X.
  vol_Of(X,Y) denotes Y is the volume of substance X.
  den_Of(X,Y) denotes Y is the density of substance X.
  has_greater_den(X,Y) denotes X substance has greater density than substance
  liquid (X) denotes X is liquid Y.
  mass_Of(X,Y) denotes Y is the mass of substance X.
  vol_Of(X,Y) denotes Y is the volume of substance X.
  den_Of(X,Y) denotes Y is the density of substance X.
  has_greater_den(X,Y) denotes X substance has greater density than substance Y.
  liquid(X) denotes X is liquid.
  float(X,Y) denotes X is float on Y if X has greater density than Y.
  sink(X,Y) denotes X is float on Y if X has greater density than Y.

- *Knowledge/Rules*:

```
% mass of clay is 90g.
mass_Of(clay,90).

% mass of wax is 70g.
mass_Of(wax,70).

% mass of water is 80g
mass_Of(water,80).

%mass of oil is 60g.
mass_Of(oil, 60).

%mass of alcohol is 50g.
mass_Of(alcohol, 50).

% volume of clay is 10
vol_Of(clay,10).

 % volume of wax is 10
vol_Of(wax,10).

% volume of water is 10.
vol_Of(water,10).

%vol of oil is 10
vol_Of(oil,10).

%vol of alcohol is 10.
vol_Of(alcohol, 10).

%oil is liquid
liquid(oil).

%alcohol is liquid.
liquid(alcohol).

% water is liquid.
liquid(water).


% density of  substance X  is Y if mass of X is A and volume of X is B then Y = A/B.
        den_Of(X,Y):-mass_Of(X,A),vol_Of(X,B), Y=A/B.
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% density of substance X is greater than substance Y if value of density of X is
greater    than value substance Y
        has_greater_den(X,Y):- den_Of(X,A),den_Of(Y,B),A>B, X!=Y.

% X floats on Y if density of X is less than density of Y and Y is liquid
        float(X,Y) :- den_Of(X,A),den_Of(Y,B), A<B, liquid(Y).
        float(X,Y) :- den_Of(X,A),den_Of(Y,B), A<B, liquid(Y),liquid(X).

% X sinks on Y if density of X is greater than density of Y and Y is liquid
        sink(X,Y) :- den_Of(X,A),den_Of(Y,B), A>B, liquid(Y).
        sink(X,Y) :- den_Of(X,A),den_Of(Y,B), A>B, liquid(Y),liquid(X).
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